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ROAD ADMINISTRATION AND MAINTENANCE.

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POPULAR SCIENCE LECTURE DELIVERED AT WITHERSPOON HALL, FRIDAY EVENING, JANUARY 28, 1910.

[In the following pages the subject indicated by the above title is treated from the economic and administrative points of view, thus affording a desirable supplement to the technical and practical details presented on the same subject in the paper read by Mr. W. H. Fulweiler at the stated meeting of the Institute, June 16, 1909, and printed in the issues of the JOURNAL for September and October following. The comparison which the present author is led to make between the various European systems of road economy on the one hand and between those and the American system on the other, is especially instructive.]

IT is interesting to note that almost without exception, from the dawn of history to the present time, those nations which have ruled the world have been great road builders.

Egypt, Babylon, Carthage, Rome and France have each in turn held supremacy as world powers and as great road builders. The earliest authentic records of permanent roads are found in Egypt. A little to the east of the Great Pyramids are the remains of a great stone causeway. This is no doubt the historic highway which Herodotus styles the Great Egyptian Road, and

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

on which King Cheops employed 100,000 men for a period of ten years. The historian informs us that this road, when completed, was of massive stone blocks ten feet in thickness, and lined on either side with temples, mausoleums, porticos and statues. The main purpose of this road was to afford a passage over the sandy desert for the tremendous quantities of stone and other material needed in the construction of the Great Pyramids.

Babylon, the city of hanging gardens and great walls, did not neglect the construction of roads and bridges, which were so essential to her military and commercial supremacy. Strabo informs us that the streets of Babylon were paved about 2000 B.C., and that splendid thoroughfares radiated to Memphis, Susa, Ecbatana and Sardis. Herodotus speaks of a great royal road extending from Susa to Sardis, a distance of about 312 miles, along which stations were established at intervals of 18 to 25 miles, where the couriers were supplied with fresh mounts. The distance travelled by these couriers is estimated at from 60 to 120 miles a day. It is asserted that asphalt was used as a mortar in building the great walls around Babylon nearly 2000 years before Christ.

The Romans are generally supposed to have learned the art of road building from the Carthaginians, though authentic records of this seem lacking. The destruction of Carthage was so complete that scarcely a trace is left of her ancient road system to tell either of its extent or its character. In Gaul, no less than 13,000 miles of road are said to have been improved, and in Britain at least 2500 miles. The great military roads which crossed the Alps traversed westward through Gaul to Spain, and eastward to Austria and the regions of the Danube, and even Africa and Asia were included in this great highway system. It is estimated that under present conditions such roads as the Appian Way would cost upward of $200,000 per mile, for the Roman system of construction was crude, expensive, and far more massive than conditions required.

After the fall of Rome a long period of inactivity followed, and the roads were allowed to fall into ruin and decay. It was not until the time of Louis XIV that any decided effort was made to again improve the roads of Europe. Under the administration of Colbert as Comptroller of Finance, which began in 1661, 15,000 miles of broken-stone roads were constructed. This

was done under the old feudal Corvee, or forced labor system, which imposed an almost unbearable hardship upon the peasantry. The Corvee was finally abolished in 1787.

The present superb road system of France was founded by Napoleon. He built many great roads throughout the Empire, among others the road over the Simplon Pass, which was begun in 1800 and required six years for completion. In 1775 the great French engineer, Tresauget, published the first treatise

FIG. 1.

Road in Lauterbrunnen, Switzerland.

on broken-stone roads, and also devised the system of continuous repair which is still practised by the French government. Too much credit cannot be given to the work of Tresauget. He was the real father of modern road building, and his work preceded that of MacAdam and Telford by about forty years.

In seeking a comparison between the systems of road administration in Europe and the United States by which we may profit in working out our road problems, we should go deeper than methods and practice and endeavor to understand the principles underlying each system. Administrative control of roads in

England and France, for example, has always followed diametrically opposite courses, the English always clinging to localized control, authority and responsibility, and the French throughout their entire history adhering to the plan of extreme centralization, whereby power began and ended with the central government. We are, therefore, justified in describing the road system of England as resting upon the basic principle of localized control and the French system as resting upon the basic principle of centralized control. Germany, being a confederation of states, affords an example midway between the extremes represented by

FIG. 2.

Bad road. Pointsville, Ky.

England and France, while Switzerland having peculiar conditions by reason of geographical location, area and source of revenue, affords an exceptional example for study. I shall, therefore, confine my observations to the systems of administrative control in England, France, Germany and Switzerland, and endeavor to point out the salient features of each, and to institute such comparison with American systems as will best aid in arriving at a determination of our points of weakness and of strength. I shall include in my analysis of road administration the very important subject of road maintenance, which, although the product of effective administration, is so vital as to be worthy of special treatment and discussion.

The basis of the French system is the School of Roads and Bridges, one of the finest technical schools in the world, and maintained at the expense of the national government. From the graduates of this school are chosen the highway engineers who are entrusted with the building and maintenance of the roads in France.

At the head of the administrative organization is an inspector-general of bridges and highways, under whom are chief engineers

FIG. 3.

Tarred road under construction. Ithaca, N. Y.

in charge of the road work of single departments and communes. Single subdivisions of departments are under the direction of district engineers and assistant engineers, the latter being equal in rank to non-commissioned officers in the army. The subdivisions are under the direction of principal conductors and ordinary conductors. Next in line come the foremen of construction gangs, the clerks employed at headquarters, and finally the cantoniers or patrolmen, each having from 4 to 7 kilometers of highway under his immediate supervision. This great administrative machine, working in complete harmony with definite lines

of responsibility clearly established, accomplishes results with military precision and regularity. And, in this great army of workmen, not the least important unit is the cantonier or patrolman, who has charge of a single section of the road. He keeps the ditches open, carefully fills holes and ruts with broken stone, removes dust and deposits of sand and earth after heavy rains, trims the trees and bushes, and when ordinary work is impossible he breaks stone and transports it to the points where it is likely

FIG. 4.

Tarred road completed. Ithaca, N. Y.

to be needed. He brings all matters requiring attention to the notice of his chief. The conductors go over the road at regular intervals and direct chief cantoniers, and all reports are transmitted to the central authorities, so that at any time the exact condition of the roads throughout France may be ascertained. Each year the conductors prepare estimates of necessary expenses for the next year under three heads, namely, Maintenance, Heavy Repair and New Work, and the government appropriations are based upon these careful estimates.

The first law in England relating to highways, of which we

have any record, was passed in 1285 and directed "those ways to be enlarged where bushes, woods or dykes be, where men may lurk." In 1346 a law was passed granting permission to levy toll on some of the roads leading out of London. This was the beginning of the toll system, which was as unsatisfactory as the parish system. The foundation of the statute labor system was laid in Great Britain in 1555 when an act was passed providing for the working of the roads in each parish by forced labor. Turnpikes or toll roads were first legally inaugurated throughout

FIG. 5.

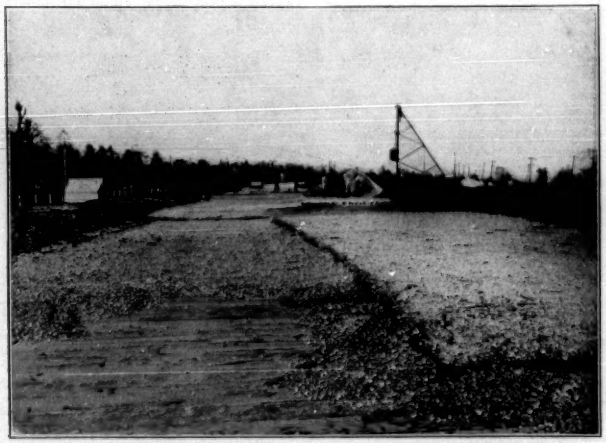
English tar spreader. Proed Aitken Machine.

England in 1663, and for a time gained considerable popularity. During the period from 1700 to 1770, 530 turnpike acts were passed by Parliament, and in 1840 there were in England and Wales 104,772 miles of turnpike road. The wastefulness and expense of this system became increasingly apparent and aroused such hostility on the part of the people that armed bodies of men assembled for the purpose of destroying the toll-gates. In 1871 the census showed that 5000 persons in England and Scotland were engaged in merely collecting tolls. In 1857 Ireland freed itself from toll-gates, and turnpike trusts were done away with

in England and Scotland by an act of Parliament in 1878. Since that time the policy of extreme localization has been somewhat modified by the more rational and practical plan of combining parishes into highway districts and requiring the county to bear a portion of the burden of maintaining the main roads.

There are at present 149,759 miles of road in England, for which the annual expenditure for the year 1905 to 1906 amounted

FIG. 6.

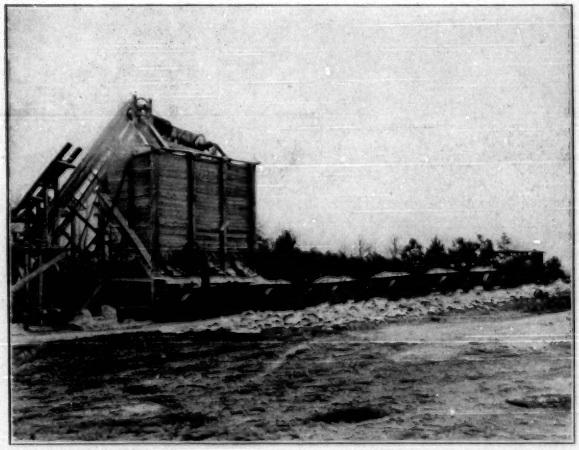


Constructing shell road on plank foundation. New Orleans, La.

to $78,059,000. The annual road expenditure per mile in England will thus be seen to be about $520 per mile as against about $38 per mile in the United States. In view of the fact that most of the principal roads of England have already been constructed, this large annual expenditure would appear to be devoted in a large measure to maintenance. It would also seem that a road system which requires an outlay of $520 per mile for its entire mileage must be inefficient and costly. The explanation of this is found, perhaps, in the fact that in England the maintenance of the public highways devolves entirely on local authorities.

Jurisdiction over the road is vested in, first, the county boroughs; second, the county councils; third, the urban district councils; fourth, the rural district councils. The county boroughs are certain large towns which hold charters from the crown entitling them to the privilege of self-government. In this the maintenance of the highways devolves entirely upon the borough or town council. In most counties the maintenance of the highways devolves upon urban councils in the urban districts and rural coun-

FIG. 7.



Crushing plant, traction engine and train. Atlanta, Ga.

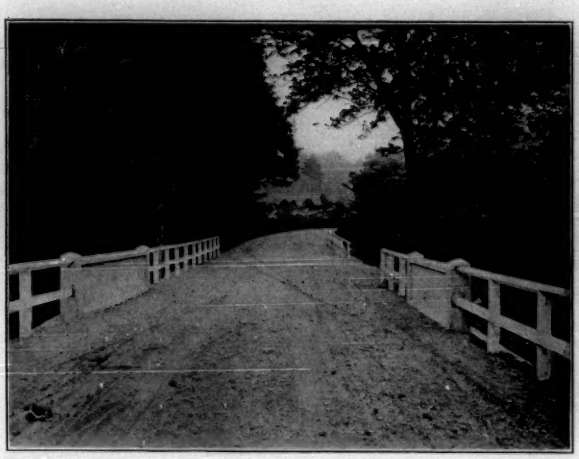
cils in the rural districts. The only exception to the control of the urban and rural district councils is in the case of main roads which are highways between large towns, and the maintenance of these roads devolves upon the county councils.

As to skilled supervision, it may be said that no qualifications are required by law to be possessed by the men in charge of road building and maintenance, but it is the general practice, at least in important districts, to appoint experienced highway engineers for this work. It will thus be seen that the English

system lacks strong central control in the counties, there being four different classes of government units, each acting largely independent of the others.

Germany is a confederation of States, and it follows that road administration is conducted separately by each State of the Empire. The Imperial Government exercises very little control over the highways, and does not in any way contribute toward their construction or maintenance. The Kingdom of Saxony

FIG. 8.



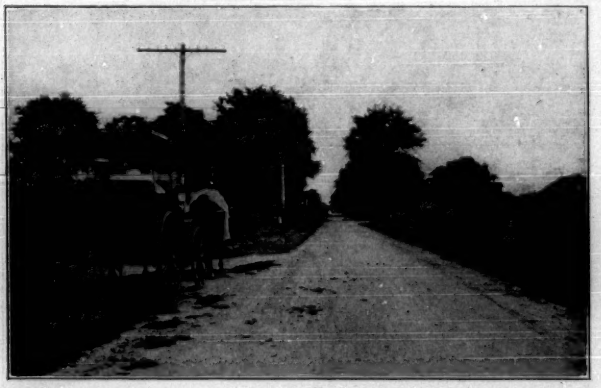
Macadam road. Chelmsford, Mass.

may be taken as a representative State of the German Empire. In Saxony the highways are divided into State roads, county roads and private ways. The State roads comprise those which are built and maintained by the State. The county roads are generally termed communicating roads, and are built and maintained at the expense of the parishes through which they lead. A striking feature of the Saxony road system is the practice of planting fruit trees along the road. The fruit yields a revenue of about $40,000 a year from the State roads, while the amount

obtained from the fruit grown on the county roads represents a much larger sum.

The State roads are cared for by a commission of engineers. The kingdom is divided into 17 road districts, in each of which there is a road inspector. Under these inspectors are road masters who are employed constantly throughout the year. Each road master has about 37 miles of road under his direction and a road force of about 15 men. In the case of the minor roads, the direct responsibility is borne by the county authorities. They

FIG. 9.



Brick road. Monmouth, Ill.

levy and collect the revenues necessary for maintenance and new construction. The communities engage the road employees for the continued care of the highways. The technical supervision, however, is exercised by the road masters of the State force.

The road system of Switzerland is local in character, the various cantons having jurisdiction over the roads within their respective borders. Each canton has at the head of its road system an engineer with capable assistants. In the canton of St. Gaul, which is fairly representative, there are under the control of the engineers 5 inspectors or road masters who are assigned to certain districts in the canton. The engineers and their assist-

ants must have an academic education and possess a diploma from the Polytechnic Institute, while the road masters are required to have a good technical education.

It is apparent from the foregoing that while the units of administration in European countries range all the way from the localism of England to the highly centralized system of France, through varying degrees, skilled supervision is provided for by all of the systems, as well as an ample cash revenue sufficient to en-

FIG. 10.

Split-log drag on earth road. Arlington, Va.

able the engineers to carry out the plans for improvement and maintenance. England is the most striking example of extreme localization, and, it is a significant fact, also the most striking example of lack of uniformity in road work and of excessive expenditure in proportion to mileage. It is also significant that the most perfect road system is that of France, which is admittedly the most highly centralized of all the road systems. France, with a total mileage of about two and one-third times that of England, expends about the same amount annually for mainten-

ance. Certainly the inference must be plain, that centralization makes for economy and efficiency in the administration of the public roads.

It is instructive to contrast the developments in the United States with those in Europe. In mileage we have the most extensive system of roads which any country has ever possessed since the world began. During all the years since the white man first blazed a path through the wilderness in North America, our roads have been expanding in an ever increasing network, until we have to-day about 2,155,000 miles. Year by year we have been frittering away our millions maintaining the roads in their primitive condition, until the yearly tribute of road taxes in the United States amounts to over $80,000,000, and our army of road overseers and supervisors has grown more than 100,000 strong. England, with only 150,000 miles of road, expends about $80,000,000 a year, or nearly fourteen times as much per mile. According to the latest road census we have less than 40,000 miles of road surfaced with stone, or less than 2 per cent. of our total mileage, and practically no provision for maintaining even these. Small as our annual expenditure for roads has been, it has aggregated during the forty years from 1870 to 1910 a total of upward of $2,600,000,000. We may, therefore, say that road building in the United States, considering area, population and wealth, is practically at the same point at which it stood 40 years ago, and the $2,600,000,000 expended have produced few appreciable results.

The reason for this is not hard to find. When we turn to the subject of road administration in the United States we find that about half of the States are operating under practically the same road laws as prevailed in England when America was a colony. This system of road administration provides for the payment of road taxes partly in labor, and localizes the work to an extreme degree. Organization is almost entirely lacking and no requirements are made to secure skill or knowledge on the part of the road officials. With few exceptions, no system of accounting is in force, and no definite lines of authority are established, such as would guarantee the wise and equitable conduct of the work.

In the last 20 years a number of the States have gradually broken away from this antiquated system, and it is to these

States that we must turn for examples of the best results in road building in the United States. About half of our States at present have adopted in principle or practice, or both, the system of centralizing conduct of all parts of the road work in the State under a State highway department, thereby securing uniformity in methods, economy and skill in supervision. In some of the State highway departments the work is educational and investigative, with a view to ultimately giving these departments administrative powers. Some of the States, notably Kansas, Missouri and West Virginia, have provided for skilled supervision in the counties through the appointment of county highway engineers. In most of these States appropriations have been made from the State treasuries, or the aid of the State convict force has been given toward carrying on road work throughout the counties.

I desire to comment particularly upon what I consider to be the most important point in highway work, and one which should engage the attention of American road builders and legislators at the present time—that is, road maintenance. In the past, by far the largest portion of our annual expenditure has been for maintenance of our unimproved roads in almost their primitive condition. Now that we are actually building roads which compare with the best of Europe, it is of the utmost importance that we make provision for the safeguarding and maintaining of these roads built at so great an expense.

In a careful study of the highway laws which have been enacted in the past 15 years, I find almost no provision for maintenance, although large sums are authorized for construction. The erroneous impression generally prevails that when a so-called permanent road is constructed it is there for all time, and the expense has practically all been met in the first cost. I have investigated the cost of maintaining roads in the leading countries of Europe, and the figures may almost be said to be a revelation. In 1901 England and Wales maintained 26,598 miles of main road at a cost of $370.34 per mile. In 1907 England and Wales maintained 27,556 miles of main road at a cost of $446.74 per mile, or, in six years the cost of maintenance had increased $76.10 per mile, an increase of over 20 per cent. In France the increase in cost of maintaining the national roads has been about 5 per cent. in the same period. The cost of maintaining main and urban roads in England and Wales in

1905 and 1906 was $440.47 per mile. In France the cost of maintaining all roads during 1904 was $243.33 per mile. While these last figures are not strictly comparable, one being for 1904 and one being for 1905, yet the mere fact of one year's difference in time fails to explain the difference of $197.14 per mile in cost of maintenance—the natural inference being in favor of the superiority of the French system. In 1906 the average cost of road maintenance was $214.13 per mile. In Belgium the annual cost of maintaining the provincial roads is $277 per mile.

These figures express most forcibly two facts: first, that even the best of improved highways are not self-maintaining, and second, that the cost of maintenance varies tremendously with the degree of centralization of the administrative organization which has the roads in charge. France, with its most highly centralized organization, is maintaining her roads at about 54 per cent. of what it costs England and Wales with her very local and loosely centralized organization. Furthermore, the alarming increase in the cost of maintenance has been far more rapid in the countries with local and poorly organized systems of highway administration. We have just seen that while the rate of increase in maintenance from 1901 to 1907 in England and Wales was over 20 per cent., it was only 5 per cent. during the corresponding period in France. In England the maintenance is intermittent and varies with the ideas of the local administrative units. In France the maintenance is continuous and highly specialized.

Many of our States have spent and are spending large sums of money on their highways, with but little thought or provision for maintenance. If experience of European countries is of any value, this must prove disastrous in two ways; first, the cost of maintenance will be high the more local and loosely centralized the organization for maintenance; second, systems of intermittent maintenance are sure to increase in cost from year to year as they have in Europe. It is high time that our legislators take note of these facts and provide ways and means so that our roads constructed at so great cost can be efficiently and economically maintained and not allowed to go to ruin, and that exhorbitant sums need not be expended in fruitless efforts to maintain them unsystematically and in an unscientific manner.

It must also be evident from a study of expenditures in

Europe that our road revenues are entirely inadequate. While our annual expenditure of $80,000,000 may seem a large sum, it is only about $38 per mile to meet all new construction, bridge building and other class of maintenance. We not only must have more money for building roads, but also definite provision for maintenance, a system of continuous repair and a centralized, skilled supervision.

MEMORANDUM OF WORK OF THE OFFICE OF PUBLIC ROADS.

The Office of Public Roads was established under an Act of Congress approved March 3, 1893, making an appropriation of $10,000 to the Department of Agriculture for carrying out the following provisions:

Making inquiries in regard to systems of road management throughout the United States.

Making investigations in regard to the best methods of road making.

To prepare didactic publications on this subject suitable for publication, and to assist the Agricultural Colleges and Experiment Stations in disseminating information on this subject.

The work of the Office was, at first, of necessity very limited. In 1897 the construction of short sections of sample roads under the supervision of skilled road builders from the Office was begun in a small way, in co-operation with the various Agricultural Experiment Stations.

In December, 1900, a testing laboratory was established for determining the value of different road building materials, and two years later the appropriation for the Office was increased to $20,000, the bill also providing for the investigation of the chemical and physical character of road materials. From this modest beginning, the work of the Office has grown in a conservative way until at the present time the annual appropriation amounts to about $117,000.

The work of the Office is entirely educational and investigative. In the educational work, an effort is made to arouse a vigorous yet conservative sentiment in favor of the betterment of public roads. Advice and suggestions are freely given upon application, intending to aid in bringing about needed reforms in legislation and administration and to introduce by practical and instructive methods the form of construction and maintenance best adapted to each locality. Every improvement in methods and materials with which the Office becomes acquainted is in turn given out to the people to be utilized as fully as practicable.

Briefly summarized, the educational work of the Office may be said to have for its objects:

1. Reforms in road laws.
2. Reforms in road administration.
3. The introduction of the best methods of construction and maintenance.
4. Improvement in the efficiency of local road builders.
5. The utilization of the most suitable road building materials available.

In carrying out its educational policy, the Office has availed itself of three very effective mediums:

1. The publication and wide distribution of government bulletins.
2. Practical lectures and expert oral advice.
3. The building of object-lesson or demonstration roads.

The results thus far accomplished in the educational field have been most gratifying. The Office has issued upwards of 200 publications, including its annual reports. These publications deal with nearly every phase of road work and most of them are for free distribution to the public. The bulletin on macadam roads tells in a plain, practical way what a macadam road is, how it should be built, how it should be maintained and what the various materials are and how they should be used.

The bulletin on sand-clay roads gives similar information for this class of construction.

A bulletin has also been issued telling in detail how to construct and use a split-log drag on an earth road. The experimental work of the Office is fully set forth in various publications in order that they may be utilized to the fullest extent by other investigators.

The lecture work covers a wide field ranging from informal talks before farmers and county-road officials to papers and addresses presented before great organizations, national in their scope, such for example, as The American Society for Testing Materials; the American Society of Civil Engineers and the American Road Makers' Association.

The Office does not maintain a corps of trained lecturers, but its engineers and practical road builders are utilized for this purpose with very great success, because they know whereof they speak. In most cases, the Office pays the entire expenses of their assignments, although it is not an invariable rule, as a co-operative sharing of the expenses is arranged when practicable.

The Office employs a corps of engineers which has come to be recognized as a body of consulting specialists in highway engineering. This work covers so wide a field geographically that in the course of a few years these men become familiar with practically every condition, every material and every method of construction. It is quite natural, therefore, that they should be called upon to advise upon intricate and difficult points of road building throughout the entire country. This expert examination and advice is conducted independently of the regular object-lesson road work.

In the building of object-lesson roads, the Office has found perhaps its greatest field of usefulness. For many years the Office furnished the engineers and experts to lay out, plan and erect the building of these object-lesson roads, as well as the machinery with which to do the work, but the furnishing of road machinery has been discontinued, and the Office is now demonstrating what can be done with facilities locally available. The old plan of furnishing machinery involved considerable delay and expense, and established a standard which could only be continued through the purchase of a similar equipment by the local authorities. Since the practice of furnishing machinery has been discontinued, the Office has about trebled the amount of work done and has reduced the cost.

Another improvement has been made in this project, in having the instruction given by the engineers apply practically to the entire road system of a given locality, the actual construction, however, being confined to a small section of road.

Since its establishment, the Office has constructed about 364 object-lesson and experimental roads in 35 States, illustrating the construction of macadam, brick, gravel, sand-clay, burnt-clay, shell and earth-roads, as well as many experimental roads of special materials and binders. This assistance is granted free of cost to local communities, the Office requiring only a simple form of application, in which local authorities agree to furnish the rights-of-way, the necessary machinery, materials, labor, fuel, etc., and in which the Office agrees to pay the salary and entire expenses of the engineer so assigned. In the building of these object-lesson and experimental roads, the Office has been instrumental in saving many hundred thousand dollars in the aggregate, through the selection of materials; the substitution of correct methods for incorrect methods, and less expensive types

of roads for the more expensive types, where, by reason of peculiar conditions, the efficiency of the road was not sacrificed by the change.

For example, Pike County, Alabama, had determined upon a large bond issue to be expended in the building of gravel and macadam roads. Upon application from the local authorities, an engineer from this Office was sent to Pike County, and after due examination found ideal conditions for sand-clay roads, and induced the local authorities to change their plans so as to utilize to the fullest extent this cheaper form of construction. To-day, Pike County has over 200 miles of superb sand-clay roads, built at an average cost of $600 per mile, which is about one-fifth of what the macadam roads would have cost.

GOVERNMENT STUDYING CONDITIONS IN YELLOW PINE FORESTS OF THE SOUTHWEST.

A study of conditions in the yellow pine forests of the Southwest, made during the past season by the United States Forest Service at the recently established Coconino Forest Experiment Station, has brought out very strikingly the difficulty of securing natural reproduction in this type of forest.

In northern Arizona, perhaps at least half of the forest is without young growth of any kind, and old cuttings are frequently barren wastes. The most important factors in bringing this about are the climate, fire, methods of cutting, disposal of brush, and grazing; in most cases two or more of these factors work together in preventing reproduction.

Climatic conditions, even when they do not injuriously affect the older trees, are apt to be especially unfavorable for the establishment of a good crop of seedlings, and curiously enough, in a region noted for its heat and aridity, frost is one of the most serious enemies of the young growth. The rainfall is very unevenly distributed throughout the year, and while in most of the yellow pine region it probably averages about twenty inches, this comes mainly in midsummer and winter.

Spring is the most arid season of the year, and it is almost impossible for seedlings to get started then. The result is that a majority of the seeds germinate during August, and not having time to fully complete the season's growth, are killed by early fall frosts. Foresters who had previously investigated this problem had realized in a general way the importance of frost, but it was not until actual experiments by means of sample plots were made that this point was definitely settled.

Owing to the extremely trying climatic conditions, some protection to the young seedlings for the first year or two is necessary. Consequently light cuttings are favorable, and the disposal of brush by scattering rather than by burning helps to protect the seedlings from the weather. The greater part of the region is quite heavily grazed, and experiments have shown that sheep, in particular, do a great deal of damage to young seedlings. Sample counts showed that within a pasture from which sheep were excluded, only 5.4 per cent. of the young trees were injured by the grazing of burros and cattle, while immediately outside of this same pasture, where the sheep were allowed to run at will, 28.2 per cent. of the young growth was damaged. Trees up to three or four feet in height are apt to be injured in this way, but the full extent of the damage is often not realized, since the inconspicuous young seedlings are damaged most severely. Fires, of course, completely destroy young growth on burned over areas, and their prevention is absolutely necessary if a satisfactory second crop is to be secured.

While the study has not yet been completed, the preliminary results are of great practical interest and value, and point to the methods of management which must be used in this type of forest. Light cuttings, disposal of the brush by lopping and scattering, and the exclusion of sheep until the cut-over areas have a satisfactory young growth, seem to offer the best means of furnishing a sufficient supply of seed and of protecting the young growth from unfavorable weather conditions and from destruction by grazing.

SECTION OF PHYSICS AND CHEMISTRY

(*Stated meeting, held Thursday, March* 3, 1910.)

AN ANALYSIS OF ILLUMINATION REQUIREMENTS IN STREET LIGHTING.

BY

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[The data on glare effect submitted in this paper is approximate rather than exact. It is derived from a very carefully planned and conducted experimental research on this subject, which, however, is intended merely as preliminary to a more extended research that the author hopes to conduct. The data is, nevertheless, amply exact to reliably indicate the order of magnitude and character of the factors concerned. In obtaining the data, a light source of approximately 50 sq. in. projected area and having a roughly uniform intrinsic brilliancy was used; the data, therefore, is probably most closely correct for light sources approximating this projected area.]

It is profitable to preface a study of street lighting by a glance at the historical development of this subject. The history of street lighting shows four quite clearly defined epochs, the last of which we are just entering. First there was the epoch, stretching back into prehistoric times, when the moon was the only source of street illumination in the primitive settlements of man. Then comes the long epoch, from early Grecian days down to about the beginning of the eighteenth century, when the moon was supplemented by a torch or lantern carried by those who found occasion to use the streets by night. The third epoch, the epoch of street lighting as a public undertaking by the community, began in a very modest way about 1736, and may be taken as extending down to the present time. The movement towards public street lighting, once started, made steady yet rather slow progress for a century and a half, until about 1880, when the introduction of the arc lamp, followed fifteen years later by the introduction of the Welsbach mantle, gave a great impetus to the movement. The last twenty years of what I have here designated as the third epoch has been

strikingly characterized by a rapid and great advancement in the mechanical and operating characteristics of street illuminants, and in their efficiency. In our own country this advancement has been chiefly due to the masterful and vigorous development work of the leading arc and incandescent lamp manufacturers and of that great corporation which stands behind most of the gas mantle street lighting of America. It is not surprising, therefore, to find that these commercial interests have so centred their attention on operating characteristics and efficiency that they are only just beginning to awake to the dawn of a new epoch which alone has been made possible by the fruits of their efforts.

We are standing to-day in the dawn of a new epoch—the epoch of street illumination as contrasted with street lighting. Just as the perfection of the elevator made the skyscraper possible and brought about a new epoch in the architecture of our city business sections, so the high efficiency and the satisfactory operating characteristics of our most modern street illuminants makes possible a real illumination of our streets, instead of the splashes of light with which we have had perforce to be content in the past. Just as the growing congestion of our cities demanded the tall building, so the growing and already extensive use of our streets by night demands adequate street illumination. It becomes, therefore, at the present moment a matter of peculiar interest and importance to determine the illumination requirements which must be met in order to obtain adequate street illumination.

The problem of illumination is a complex, 'molecular' one rather than a simple, 'atomic' one. To be adequately studied, the problem of illumination must be split up into its constituent, subordinate problems, and these studied separately and in their relations to each other.

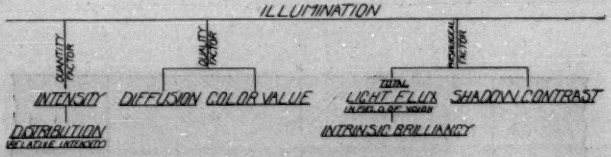
Fig. 1, repeated with a slight revision from a previous paper* by the author, schematically shows the subordinate problems which combine to make the problem of illumination. Intensity and distribution are linked together as quantity factors. Distribution is simply the problem of relative intensities, of proportion of intensities at different points. Diffusion and color

* Sweet, Standard Relations of Light Distribution, Transactions of the Illuminating Engineering Society, November, 1909.

value are grouped together as quality factors, though each is, of course, independent of the other. Total light flux in the field of vision and shadow contrasts are two closely related yet separate factors affecting the efficiency of the eye, the receiving apparatus. Subordinate to the factor of total light flux in the field of vision, but of the most vital importance, is the factor of the intrinsic brilliancy of light-giving or light-reflecting objects in the field of vision.

The relation of the above analysis to the problems of street illumination becomes at once apparent. There are two results to be achieved in adequate street illumination which are both of such paramount importance that it is properly a matter for individual opinion as to which should be ranked first. These are the avoidance of glare effect and the obtaining of an approximately uniform degree of illumination at all points along the

FIG. 1.



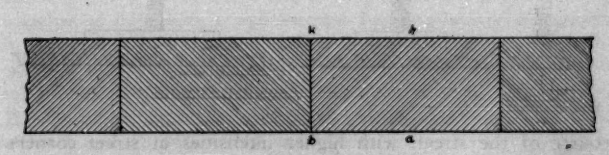
course of the street, with higher intensities at street corners. These two results can only be obtained, the one by the correct solution of the allied problems of intrinsic brilliancy, total light flux, and shadow contrasts, the other by the correct solution of the problem of distribution (see Fig. 1).

Let us separately take up in preliminary fashion each of the results sought and define it a little more exactly.

Glare effect results whenever, throughout any infinitesimal period of time, an amount of light continues to fall upon the actively visualizing portion of the retina of the eye sufficient in quantity to cause chemical changes more rapidly than the regenerative functions of the eye can keep pace with. Thus when an eye, which has been exposed for some time to conditions of dark with resultant pupillary expansion, is suddenly exposed to even a moderate light, glare effect results. An excessive amount of light reaches the retina through the expanded pupil, and the

regenerative functions cannot keep pace with the chemical changes induced. Rapidly, however, the pupil contracts, the regenerative functions regain their normal control, and the glare effect passes away. If now the eye be exposed to a still greater intensity of light, beyond the very limited capacity of pupillary contraction to compensate for, or if an even moderately bright light source is introduced near the centre of the field of vision, glare effect is again experienced; and this glare effect, after a brief period, reaches a certain state of equilibrium characterized by a quite definite decrease in efficiency of vision, which decrease thereafter increases in magnitude only rather slowly. We may, therefore, for convenience designate a glare condition as casual, when it results from the inability of the pupil to adjust itself instantly to a changed condition of light intensity, and as fundamental

FIG. 2.



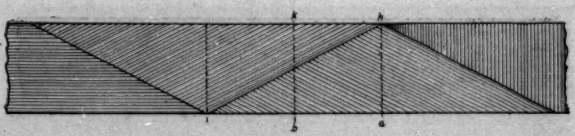
when it results from a light intensity exceeding the contractive power of the pupil to compensate for, or when it results from a light source near the centre of the field of vision.

The presence of strong shadow contrasts tends to produce a casual condition of glare. The evil effect of the shadow contrast lies in the demand it introduces for instantaneous pupillary changes of considerable magnitude when the eye is turned from the shaded to the unshaded area, or vice versa. In street lighting, this casual condition of glare is much less objectionable to the slowly moving pedestrian than to the more rapidly moving automobilist or carriage driver. It is usually sufficient, therefore, to throw the shadows toward the sidewalk and to provide against too deep shadows. The avoidance of objectionably-located shadow contrasts can only be taken care of by the proper placement of the light sources, while the intensity of the

shadow contrast can be decreased by using smaller light sources placed nearer together. The problem of shadow contrasts, while of considerable importance, is one that must be solved individually for each individual case. It needs no further independent consideration in this general study of our subject.

Brilliant, high candle-power light sources in the field of vision, the usual practice in contemporary street lighting, produce a fundamental condition of glare, with resultant heavy decrease in efficiency of vision—with probably also, be it noted, a permanently injurious effect on the faculty of vision. This fundamental condition of glare arises from the intrinsic brilliancy and total light flux of the light units employed and can only be avoided by the proper limitation of these. The study of the relations existing between intrinsic brilliancy and total light

FIG. 3.



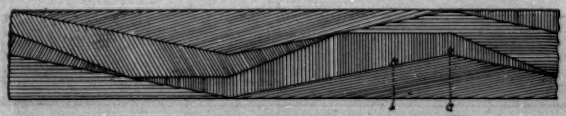
flux on the one hand, and glare effect on the other, becomes, therefore, one of the two chief purposes of an analysis of the illumination requirements of street lighting. The end sought should be the elimination of glare effect, or at least its reduction to such a permissable minimum as will not seriously decrease efficiency of vision nor be sufficient to produce eye discomfort.

The derivation of the polar curves of light distribution which will give the proper relative intensity of illumination for points along the course of the street is, as has already been noted, the second of the two chief purposes of an analysis of illumination requirements in street lighting. Here the end sought is the uniform illumination of all points along the course of the street. There is no reason either in scientific fact or in common-sense why one point along the course of the street should be more brightly lighted than another, with the exception of street inter-

sections and similar crossings later to be noted. The present almost universal condition of brighter illumination under and near the light unit is simply a concession to our present ignorance of how to obtain something better. There is, on the other hand, abundant reason to condemn this spot-lighting practice.

At street intersections and similar crossings a brighter illumination is needed, for obvious reasons. This should be of from four to eight times the intensity of the illumination along the main course of the street. Such brighter illumination is properly provided for by employing from four to eight light units each having the same light distribution as the units used along the course of the street, or by one or two light units of similar light distribution and larger size. The street intersection, therefore, presents no complication to our problem, and

FIG. 4.



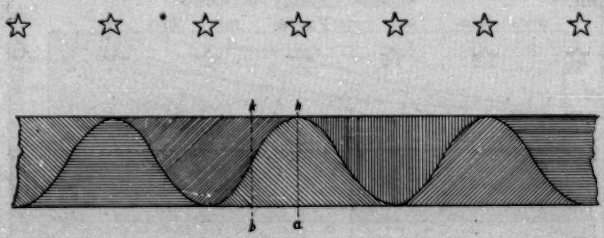
its proper treatment becomes merely a matter for adequate consideration at the time of installation.

The statement is often heard that in street lighting absolute uniformity of illumination is not required nor of any particular importance. Taken in a very strict sense, this statement contains much of truth. But this statement has been so very generally used as a refuge for loose thinking, by the scientific man as well as the layman, that it is worth a moment's careful consideration. It is true that a variation of two to one, taking the minimum intensity as unity, is only barely noticeable and is entirely permissable. But let us invariably ask our friend, who says uniformity is not required, what numerical value he will assign as ratio of maximum to minimum intensity. If he gives us four to one, or a less ratio, we will agree with him and ask him to oblige us by keeping this ratio in mind in our further

discussion. If he gives us eight to one or twenty to one or some such figure, we will disagree with him; and we will propose a hopeless task to him if we ask him to justify, by properly established scientific fact, such a ratio as permissible from any other standpoint than that of our possible inability to obtain a greater uniformity. At the same time we may profitably point out to him that the ratio in present practice most frequently falls between one hundred to one and five hundred to one.

Another much-mooted question concerns the way in which illumination should be measured, whether horizontally or perpendicular to the light ray. The latter method has been largely adopted in American practice chiefly through the influence of the commercial interests concerned, who desire to make the minimum

FIG. 5.



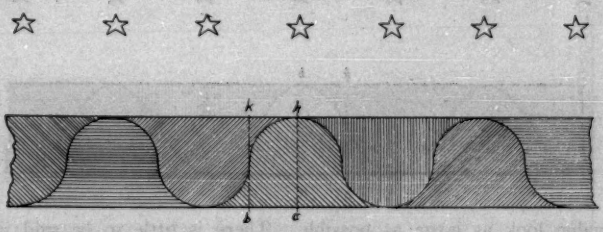
value look as large as possible. There is little to be said in favor of it except that it may help us to remain in a fool's Paradise concerning the satisfactoriness of the illumination we are getting. It is true that in street service, illumination is desired at different times on almost every conceivable plane. But the best single measure of how well these many diverse requirements are met is the intensity of illumination on the horizontal plane. The horizontal plane, therefore, which is the accepted reference plane in interior lighting, is the logical and most satisfactory basis for street illumination measurements.

The ideal to be aimed at, therefore, in street lighting, as far as intensity is concerned, is uniform horizontal illumination. On this basis we can now proceed to derive the ideal curves of light distribution. These curves once derived, we may properly take into account the fact that absolute uniformity is not of

importance: and we will only ask that the actual light distribution sought for as a practical ideal show no greater variation from our theoretical ideal than four to one in ratio of maximum positive variation to maximum negative variation as read in percentage values of the theoretical curve along the corresponding angles.

The nature of a street makes most natural a placement of light units as a line of single units extending along the street, the units being hung over the centre of the roadway or located alternately on either side. For all practical purposes, these two cases can be treated as one, the separation of adjacent units being taken as the *straight line* distance between the units, and the distribution curve derived being the correct distribution in a vertical plane passing through the unit concerned and the adjacent unit.

FIG. 6.



There are an infinite number of light distributions which will give uniform illumination from a line of light units along a line extending immediately under those units. Other considerations than the obtaining of uniformity must therefore serve to enable us to select the most desirable distribution curve.

Two such considerations are of especial importance and may therefore be applied with especial propriety. First, we should seek such a distribution as will be best suited for actual, practical attainment. This consideration is of the more importance because, as we shall find, even when maximum weight is given to this consideration, our derived curve will present considerable though by no means insurmountable difficulties of practical realization. Second, the illumination at any point should be derived from a source as near as possible in order to avoid both exces-

sively long shadows, and the glare effect which results from the high candle-power made necessary by illumination at great distances.

Fig. 2 shows one possible illumination curve. Here each light furnishes the entire illumination on either side out to a point midway to the next light. This curve would mean a light distribution in which the candle-power values dropped instantly from a maximum to zero at the angle subtended by half the separation of the units—a condition impossible of satisfactory realization. This distribution curve is also undesirable because it shows a considerably higher maximum candle-power than would be required by certain other forms of illumination curve.

FIG. 7.

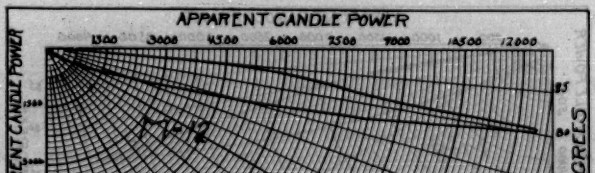
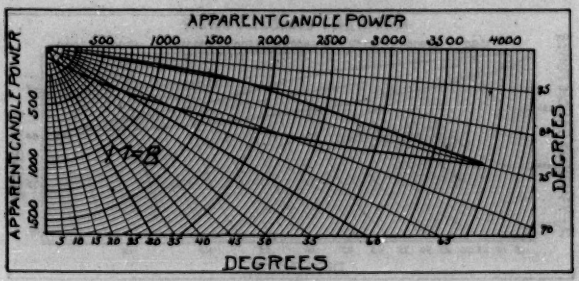


Fig. 3 shows an illumination curve in which the intensity values decrease uniformly from a maximum directly beneath the lamp to zero directly beneath the adjacent lamp. The corresponding distribution curve has its maximum at an angle subtended by the separation of the units, beyond which the candle-power values drop instantly to zero, while in addition the maximum has an unduly high value. Fig. 4 shows an illumination curve in which the intensity values decrease uniformly and reach zero under the lamp beyond the adjacent lamp. Enough has already been deduced to make it obvious that the corresponding distribution curve would be particularly undesirable. Fig. 5 shows a sine wave type of illumination curve,—a more satisfactory type than any above considered. This distribution curve has a relatively low maximum and is as well adaptable to practical realiza-

tion as any curve obtainable. It has, however, one defect. The maximum value occurs at an angle considerably greater than that subtended by half the separation of the units. To obtain minimum glare effect, the angle of maximum candle-power should be as small as possible in order that the light source may be removed as far as possible from the centre of the field of vision when the eye reaches the point toward which the maximum candle-power is directed.

Many other types of illumination curve could be given and the corresponding distribution curves shown to be open to objection. Suffice it to say that it can be established by a mathematical line of reasoning, which space limitations do not permit to be

FIG. 8.



here given in detail, that the curve which best meets the conditions imposed is such as shown in Fig. 6. This curve is formed by two circle quadrants combined as shown. The corresponding distribution curve shows a low maximum which occurs at a slightly smaller angle than that subtended by half the separation of the units. It is also as well adaptable to practical realization as any curve obtainable.

We have, therefore, obtained the ideal illumination curve from which the desired distribution curve can be easily derived. Our next task is to put these results into such form as to be easily applicable to practical conditions.

The relation between any desired illumination results and the distribution required to produce those results depends, in the type of problem under consideration, upon:

a. The distance between adjacent units.

b. The height of the light unit above the street.

That is to say, for any given separation of units and height above street, we can easily calculate the distribution curve which will produce the desired illumination result.

It is obvious that any given distribution curve will give the same proportionate illumination results so long as the relation between the separation of units and the height above street is kept constant, since so long as this relation remains constant, the angular relations are unchanged. We can combine, therefore, the factors (*a*) and (*b*) (see above), and say that the distribution required to produce any given illumination result depends upon the relation between (*a*) and (*b*). Let us call this relation *M*.

$$M = \frac{\text{distance between adjacent light units}}{\text{height of light unit above street}}$$

For any value of *M* there is a given distribution curve which will produce the desired illumination result.

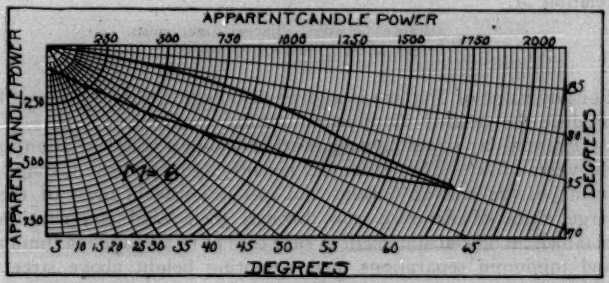
Present-day street lighting practice shows a wide variation in the value of *M*. The writer has recently addressed the managements of the central stations and gas interests in most of the large cities of America and through their kind co-operation obtained an official statement in each case as to average, maximum and minimum separations, and mounting height above street. The values of *M* thus obtained (based on average separations) vary from $M = 5$ to $M = 31$. The smaller cities would probably show in general a higher value for *M* than the large cities. All things considered, a value $M = 15$ can probably be taken as the most representative value of present-day American practice, with a marked tendency towards smaller values in the more recent installations.

Fig. 7 shows the distribution curve required to produce uniform illumination when $M = 12$. Here we are at once brought face to face with the nature of the problem that confronts us. It needs no specialist to point out that such a curve as shown is impractical for actual realization, and would be extremely undesirable, even if it were practical to obtain it, on account of the excessive glare effect resulting from the very high candle-power maximum at a large angle. It will be ob-

served that the maximum candle-power is about 130 times the minimum, or zero degree, candle-power.

Fig. 7 serves one excellent purpose. It shows concisely and beyond argument that, with a value $M = 12$ or greater, any attempt at adequate street lighting is absurd. If ignorance and a false economy compel an installation value of $M = 12$ or greater, the pretense of obtaining "street illumination" should frankly be abandoned. Instead, the lights should be installed on the basis of a system of street markers, and located where they will best serve as markers. In such case, maximum usefulness as markers will be obtained when the candle-power values at the different angles are as close as possible to, yet not ex-

FIG. 9.



ceeding, the limits imposed by the avoidance of glare effect. Be it noted that in sparsely settled districts, where the very slight use of the streets by night may not warrant adequate street illumination, such a system of markers has a very real field of usefulness. But it should avowedly be a system of markers, not an abortive attempt at street illumination.

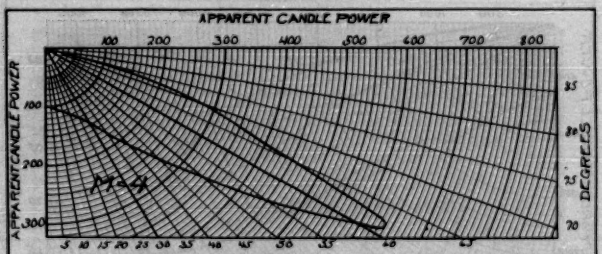
Fig. 8 shows the required distribution curve for uniform illumination when $M = 8$. Here we are beginning to approach a form of curve practical for actual attainment; but the still very high candle-power maximum is prohibited by the limitations imposed by avoidance of glare effect.

Figs. 9 and 10 give the required distribution curves when $M = 6$ and $M = 4$ respectively. These distributions are entirely practical for actual attainment. For instance, referring

to Fig. 11, the full-line curve shows the actual distribution of one make of arc lamp to-day on the market, the curve being one obtained by test by the Electrical Testing Laboratories. The dotted curve is the ideal curve for $M = 4$. It will be seen that the agreement of the two curves is admirable up to an angle of about 62 degrees. The curves $M = 4$ and $M = 6$ would also be comparatively easy of attainment with the incandescent lamp or with the inverted gas mantle. This is of especial importance since, with these lower values of M, such smaller units give amply sufficient intensity of illumination except in those business centres where night traffic is considerable.

Smaller values for M than 4 would obviously fulfill all the

FIG. 10.

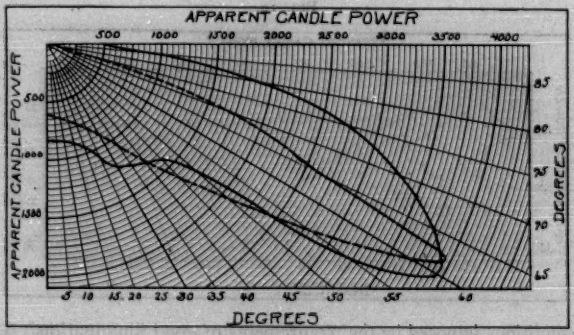


conditions imposed by the requirements of good illumination. It will later be shown by our study of glare effect that a value $M = 3$ is necessary to obtain best results whenever, on account of shaded conditions of street or other considerations, it is desirable to mount the units at a height of 15 feet or less above the street. Closer spacing of units than $M = 3$ entails a corresponding increase in installation and maintenance costs, and is not demanded by the illumination limitations of the problem.

This far in our discussion, we have considered distribution only as referred to the vertical plane passing through the light unit and its adjacent unit. We will now consider the vertical plane perpendicular to the street line. In those rare instances where the width of the street from property line to property line is greater than the separation of adjacent units, the ideal distribu-

tion in this latter plane is similar, for the lesser angles, to the distribution required by the existing value of *M*. It continues, however, to a higher maximum, turning and receding rapidly to zero above the angle subtended by the distance from the light unit to the more distant property line. When the street width is not greater than the separation nor less than three-fourths of the separation, the distribution in the plane across the street should be approximately the same as in the plane through the light units. When the street width is less than three-fourths of the separation, the distribution in the plane across the street is similar, for the lesser angles, to the distribution required by the

FIG. 11.



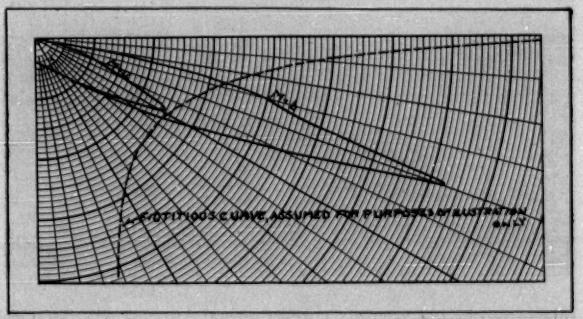
existing value of *M*. But in this case, the maximum is lower, the curve turning and receding rapidly to zero above the angle subtended by the more distant property line. In oblique planes, the distribution values should be proportionately intermediate between the values in the two planes already considered.

It is proper to note that the importance of obtaining correct distribution results in the plane perpendicular to the course of the street, and in adjacent oblique planes is rather one of obtaining maximum efficiency than of guarding against unsatisfactory illumination results.

Summing up the previous paragraphs, the requirements of good street illumination, as determined by distribution considerations, are as follows: Uniform horizontal illumination is the

ideal to be aimed at, and the approximation to this ideal in actual practice to within a four to one ratio of maximum to minimum may be taken as sufficiently close for all practical purposes. The most desirable type of curve for the illumination delivered by the individual unit is such as shown in Fig. 6. When the light sources are separated by a distance greater than six times the mounting height above street, it becomes impractical to design a unit giving such light distribution as would be required for a sufficiently close approximation to uniform illumination. When the light sources are separated by twelve times the mounting height or greater, the pretense of adequate street illumination becomes an absurdity; and when ignorance of the factors involved

FIG. 12.



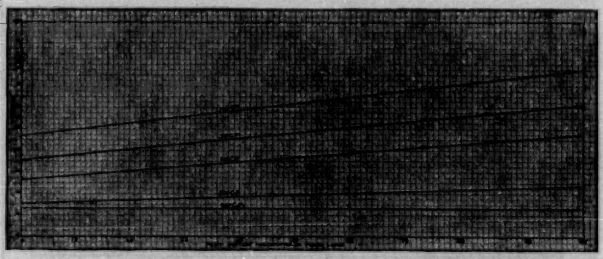
has led to such separations, best results can be attained by abandoning all pretense of street illumination and by installing the light units as a system of street markers. Separations of three to six times the mounting height are required by distribution considerations.

The second great division of our subject, the study of glare effect, has already been introduced in general terms in the earlier portion of this paper. It now remains to analyze glare effect closely, to determine the laws of operation of the conditions that produce it, and to learn the limitations which it imposes on our problem.

As will at once be recognized, the consideration of avoidance of glare effect will operate by imposing a definite candle-power

limit at each distribution angle, this limit varying only with the mounting height. In proportion as this candle-power limit is exceeded a greater or less glare effect will result. The exact relations of this limitation will be apparent by reference to Fig. 12.* Here are shown two ideal distribution curves, $M = a$ and $M = b$. It is presupposed that the circular co-ordinates have definite candle-power values assigned to them. Now for any given mounting height, there will be a definite curve of zero glare effect as illustrated by the indicated fictitious curve. Along any angle, candle-powers greater than those indicated by the zero curve will produce a greater or less glare effect. All ideal distribution curves exceeding some definite value for M will be

FIG. 13.



intersected by the zero glare effect curve. Such curves of ideal distribution, typified by the curve $M = b$, are therefore unsuited for application to actual practice, since they would introduce a more or less serious condition of glare with resultant decrease in visual efficiency. The net result, therefore, of the limitations imposed by the avoidance of glare effect, will be to eliminate for any given mounting height all curves of ideal distribution exceeding some definite value of M.

We now have clearly before us the nature of the limitations imposed by the avoidance of glare effect. There remains to be determined the exact shapes and candle-power values of the zero curves for different mounting heights.

* In this figure, a very erroneous curve of zero glare effect has purposely been assumed.

Subject to confirmation by research results, glare effect may be assumed to vary with the following factors:

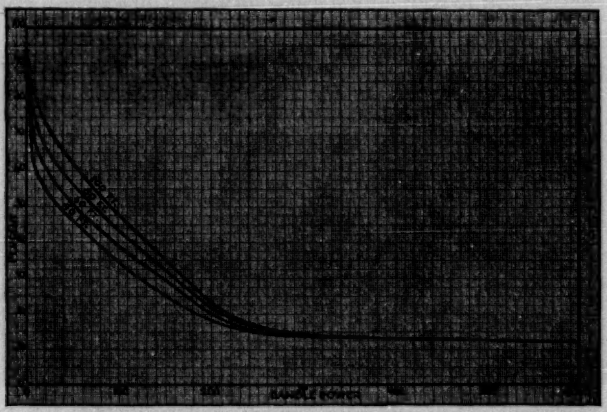
(*a*) Distance of the eye from the light source.

(*b*) Total light flux in the direction of the eye, this being measured in apparent candle-power at the distance of the eye.

(*c*) Intrinsic brilliancy of the light source.

(*d*) Angular position of the light source in the field of vision, the visualized object being assumed to occupy the centre of the field of vision.

FIG. 14.



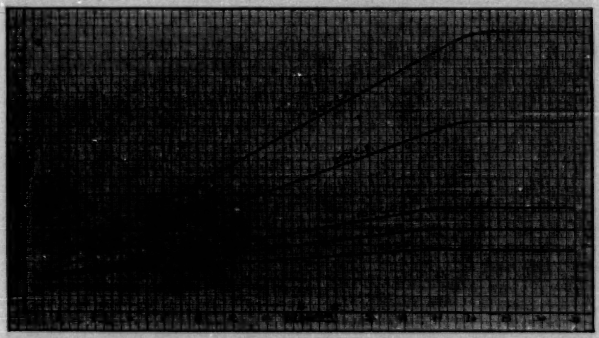
(*e*) Distance of the light source from the eye relative to the distance of the visualized object upon which the eye is focused.

In the research to be reported upon in the following paragraphs, the factor (*a*) was separately studied and determined with sufficient exactness to reliably indicate its character and approximate magnitude for distances up to 100 feet. Factors (*b*) and (*c*) were studied unseparated, as a single factor, the light flux varying directly as the intrinsic brilliancy. Factor (*d*) was separately studied and evaluated. Factor (*e*) was not investigated, the distance of the light source from the eye being in all cases taken as equal to the distance of the visualized

object. This condition corresponds to the most usual condition of actual street vision.

Heretofore no satisfactory measure of glare effect has been proposed. Since we are dealing with a psychological phenomenon, the basis of measure must obviously be a psychological one. On the other hand, the measure must be expressable in definite numerical units. A basis of measure fulfilling these requirements was conceived of for this investigation and proved a very satisfactory one. Preliminary to a more detailed description, such a measure may be described as the ratio of the two minimum light intensities on the visualized object, of magnitude just

FIG. 15.



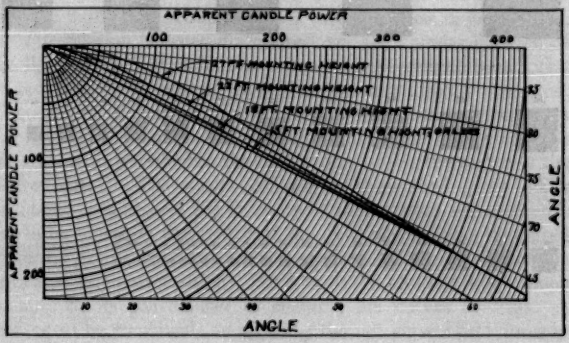
sufficient to enable its discernment, when the eye was successively exposed to the two conditions under comparison.

A careful preliminary investigation established the fact that, under widely varying daylight conditions, visual acuity was wholly independent of distance, within the limits investigated: that is to say, with any given type of visualized object, the minimum size of object which can be just barely distinguished as a separate unity is exactly proportional to the visual distance. Three different test plates, as shown in Figs. 17, 18, and 19 were employed. In these test plates, each object or unit gradation is 10 per cent. smaller than the one previous.

After establishing the fact just stated, each observer was

calibrated, the determination being made of the minimum unit gradation which could be individualized under daylight conditions at various standard test distances. The fourth larger gradation was then chosen as the test object at the corresponding distance in the glare tests. This made it certain that the test objects were, by a uniform amount, well within the limits of visual acuity under adequate conditions of illumination. Consequently the ability to visualize these objects was wholly determined by the visual efficiency of the eye and by the intensity of illumination on the object. Expressed mathematically, we are here dealing with a constant which is a function of two variables.

FIG. 16.



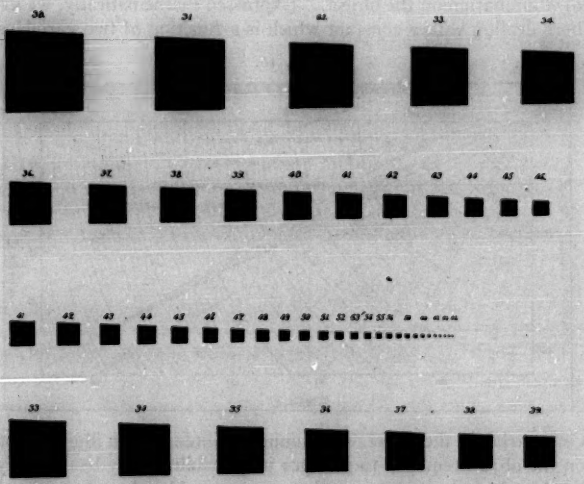
One variable, therefore, the minimum intensity of illumination on the object required to produce just-visibility, may be correctly employed as a measure of the other variable, the efficiency of the eye under any given condition. [The author believes that this basis of measurement is a very satisfactory one and has a wide field of usefulness in future investigations of this character.]

The basis of measurement being established, tests were first made to determine the relation between distance of the light source from the eye and the magnitude of the decrease in visual efficiency due to glare. These tests were made at five test stations, three independent sets of readings, one with each test plate, being taken at each station. Parallel tests were made with

different observers. The complete series was then repeated with each observer, using various other candle-power intensities of the light source. The area of the light source throughout all these tests was kept constant, at about 50 square inches, the intrinsic brilliancy thus varying directly with the candle-power, as has already been stated.

Fig. 13, derived from the test data obtained as just described, expresses the relation between glare effect and distance, the light

FIG. 17.



unit being situated beside the visualized object in the centre of the field of vision. The ordinates express visual efficiency in terms of the per cent. intensity of illumination on the visualized object which would be required for equal visual acuity were the light source entirely removed from the field of vision. It will be noted that at 12½ c.p. and an intrinsic brilliancy of 0.25 (British units), the glare effect drops off at a moderate rate with increase in distance. At higher candle-powers and higher intrinsic brilliancy, the glare effect decreases more slowly with increase in distance; until finally, at 400 c.p. and an intrinsic

brilliancy of 8, there is no measurable decrease in glare effect with increase in distance within the limits investigated.

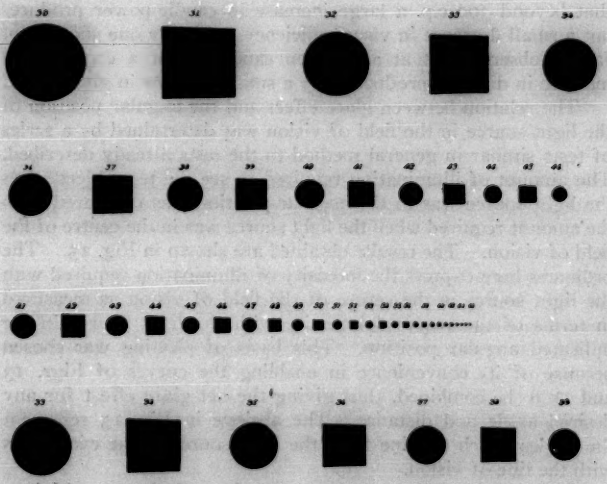
Fig. 14, derived from the same test data, expresses the relation between glare effect and candle-power (or, as it may be instead, between glare effect and intrinsic brilliancy). These curves are especially significant. It will be seen that, for all ordinary distances, the presence of a light source of even a very low candle-power in the centre of the field of vision causes a tremendous drop in visual efficiency. It will also be noted that at 300 c.p. the glare effect has nearly reached its maximum, and that beyond 300 c.p. a large increase in candle-power produces but a small decrease in visual efficiency. Finally one should not fail to observe that at any given candle-power a considerable increase in distance produces only a small decrease in glare effect.

The relation between glare effect and the angular position of the light source in the field of vision was determined by a series of tests similar in general method to the tests already described. The amount of illumination required to see the test object when the light source was in the angular position was compared with the amount required when the light source was in the centre of the field of vision. The results obtained are shown in Fig. 15. The ordinates here express the intensity of illumination required with the light source in the centre of the field of vision as measured in terms of the required intensity with the light source in the indicated angular position. This basis of plotting was chosen because of its convenience in enabling the curves of Figs. 13 and 15 to be combined, thus giving the net glare effect for any desired angle and distance. The abcissæ in Fig. 15 represent the angles which the line from the light source to the eye makes with the line of vision.

The curves of Fig. 15 express a fact of the very highest importance in the study of glare, namely, that, at an angle varying, depending on the candle-power (intrinsic brilliancy?), between approximately 22 degrees and approximately 26 degrees the glare effect reaches zero, although the light source is still well within the field of vision. This would seem to indicate that on its physiological side, glare effect is a local retinal disturbance which, when sufficiently separated on the retina from the disturbance produced by the visualized object, does not extend to or affect the latter area of disturbance. This apparent fact

seems to hold true even when a considerable time factor is introduced. Apparently pupillary contraction acts merely as a function protecting, within its very limited capacity, from a glare effect more or less suffused over the whole retina. The writer has previously believed that pupillary contraction was in itself a cause of decreased visual efficiency in that, on account of pupillary contraction, a lesser amount of light would be admitted to the retina from the visualized object. He now believes that

FIG. 18.



pupillary contraction should be regarded as a purely protective function and not, through its operation, in any sense itself a cause of decreased visual efficiency.

The practical importance attaching to these facts is of no less vital interest than the scientific. Fig. 15 means that the light instrumental in causing glare comes entirely from the polar angles above 60 degrees. In the average actual case, glare is almost wholly caused by the light between the angles of 65 degrees and 80 degrees with the nadir. The light within these angles must

be partially or wholly suppressed, as the further facts of the case shall show to be required, if glare is to be avoided.

In Fig. 12 and the text relating thereto, the operation of the curve of zero glare effect in eliminating certain curves of distribution was developed. We are now in a position to determine the true curves of zero glare effect, which, as will be remembered, will vary somewhat with the mounting height.

Fig. 16, derived from Figs. 13 and 15, gives the curves of zero glare effect for various mounting heights. Comparing these curves with the curve of ideal distribution when $M = 6$ (Fig. 9), we see at once that this curve, together with curves of larger value of M, will be eliminated on account of the serious glare effect which would result from the application of such distributions to actual practice. The curve $M = 4$, however, comes within the limitations imposed by the curve of zero glare effect, providing the scale of the $M = 4$ curve does not exceed that amount which would make the zero-degree candle-power equal to 100 c.p. The distribution curve corresponding to $M = 3$ would come well within the limitations imposed by zero glare.

Reference to Fig. 16 shows that for all practical purposes, 60 degrees is an absolute limit for maximum candle-power if serious glare effect is to be avoided. It will also be observed that an increase in mounting height, while it does not change the limiting angle for maximum candle-power, does considerably lighten the severity of the limitations at 65 degrees and above. Mounting heights of the larger values, when made possible by actual conditions, are also desirable as permitting wider separation of units with resultant decreased installation and maintenance cost.

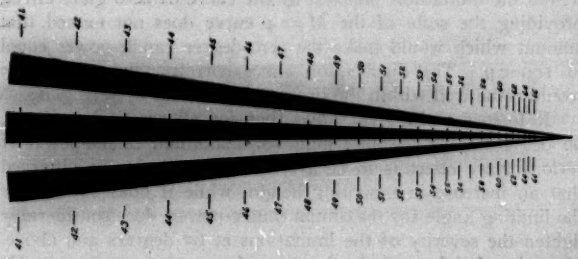
For mounting heights of 15 feet or less, the curve $M = 4$ will produce considerable glare, beyond, indeed, what proper limitations can permit. For such lesser mounting heights, as has already been pointed out, a closer spacing of units and a distribution corresponding to the curve $M = 3$ should be used.

In designing a light unit to give the desired distribution which has largest field of application, namely the distribution from $M = 4$, it will be preferable by far that the candle-power values at 60 degrees and above, be less than those made proper by the ideal curve, rather than that these ideal values be exceeded. With an ideal curve of such candle-power magnitude as would be

most useful, the candle-power values at the angles under consideration come perilously near to the glare limit, or may even exceed the glare limit. A per cent. variation from the ideal curve of four to one is, as has been pointed out (see page 366), permissable. Even a moderate condition of glare, on the other hand, is very undesirable. Practical considerations, therefore, will lead us, in the design of the actual unit, to intentionally deviate from the $M = 4$ curve at the angles of 60 degrees and above, this deviation being in the direction of lesser candle-power values.

It is of the utmost importance to note that if the glare limit is exceeded at all, it will almost of necessity be exceeded excessively. The curve of zero glare-effect runs almost instantly back to zero near the angle of 65 degrees. The glare-effect

FIG. 19.



would therefore increase with great rapidity as an angle of 65 degrees was exceeded, even in the case of a distribution whose curve approximated to one of the circular co-ordinates. The curves required for uniform illumination, on the other hand, increase with great rapidity in candle-power values to their point of turning. It is obvious that the curve of zero glare-effect must be taken as a line of absolute prohibition. If it is to be exceeded at all, it may as well be entirely ignored. For an apparently small violation of the limit will produce a decrease in visual efficiency of approximately the same order of magnitude as the maximum possible effect.

It is also of great importance to note that the curve of ideal distribution for $M = 4$ remains, though not an ideal, yet none the less the best possible curve when applied to actual conditions

where M has a larger value than 4. The curve $M = 4$ gives the best spot-lighting effect and the best marker-effect which are possible without engendering a condition of glare. This research has indicated that, for ordinary mounting heights, moderate glare is a mere name: the reality is always excessive glare. It is the opinion of the writer, therefore, that glare must be avoided, even if so important a consideration as proper distribution has to be sacrificed. And indeed, as has been shown, other conditions than glare make a proper distribution impractical or even impossible with the larger values of M. The curve $M = 4$ is to be regarded, therefore, not merely as the ideal curve for a certain relatively close spacing of light units which the public is not as yet educated up to, but as the best possible distribution which can be applied to any of our present-day spacings.

This paper is not presented, therefore, as merely expressing an ideal to be approximated to in a comparatively remote future. Rather, it should serve as a guide of immediate usefulness and application to present-day practice. And yet, as the writer is well aware, before such application has gained any great headway, there must be a vast amount of educational work accomplished. The ordinary citizen of to-day uses in his ignorance the very defect itself, the glaring character of a street illuminant, as a measure of its excellence. Such ordinary citizen would consider himself defrauded were he called upon to pay through his taxes for a street illumination characterized by absence of glare, by light on the street itself and not in the eye.

This paper, obviously, is not addressed to the ordinary taxpayer. It is addressed, through the medium of your honorable body, to the scientist, to the manufacturer of street illuminants, to the central station superintendent, to the educated and public-spirited citizen. Let these work shoulder to shoulder in the education of the public and this must eventually become a reality in a no distant future. And the rewards, whether commercial and material or as pride in a useful service accomplished, will come first and in largest measure to those of us who join in the work. So working shoulder to shoulder, let us teach the public, teach them so thoroughly that it becomes a popular catch-word, "Light on the object, not in the eye." Let us teach them that this "light on the object," can be accomplished only by a closer spacing of light units, which will mean a larger increase in in-

stallation cost, though but a small increase in operating cost: that light "not in the eye" means of necessity absence of glare; so that the excellence of a street illumination must be measured by absence of glare, rather than by the presence of glare. Thus working together, in our own time shall come the day when our streets are illuminated by night as beautifully, and with as great comfort to the eye, as the open country road lying clear in the bright moonlight.

MEXICO'S SUPPLY OF LONGLEAF PINE AND CONDITION OF NAVAL STORES INDUSTRY.

An aggregate area of 6,000,000 to 7,000,000 acres of longleaf pine, in every way suited to turpentining, briefly indicates the extent of the only partially developed naval stores resources of Mexico.

A peculiar and interesting feature of the Mexican turpentine belt is that the turpentine-producing trees are found only in the mountains at high altitudes, a condition directly reverse to that existing in the United States, where trees at an altitude of 2000 feet are unproductive so far as turpentine is concerned.

Carey B. Townsend, of New Orleans, who has spent some time investigating naval stores conditions in Mexico has given an interesting account of his observations. Speaking of the characteristics of the Mexican tree, he says:

"The Mexican turpentine pines present a different appearance from our trees in the United States. The bark is thicker, nature providing this as a protection against the cool nights of the high altitudes. The needles, too, are shorter and coarser than those of our southern pines. The appearance of the Mexican pines differs materially in the altitude in which they are found, the trees at 8000 to 9000 feet presenting a sharp contrast to those at 5000 or 6000 feet. A close investigation with proper tests convinced me that there is no difference in the yield or quality of the gum. In Michoacan, where I spent most of my time, the altitude of the camp is 6000 feet. The days are warm, but the nights invariably cool. I kept a thermometer record, and the lowest the mercury went was 50° and the highest 88°.

"Turpentine runs freely in Mexico when the temperature is 60° or above. While there is little or no flow at night, the first rays of the morning sun striking the trees start the gum running freely and this only lets up when darkness comes. I have never seen better running pines in my entire observation, which has extended from Cape Fear to the Sabine River. Owing to the cool nights it is proper to estimate the yield of the Mexican pines at 25 per cent. less than the best output of our southern pines.

"The atmosphere evidently affects the quality of the crude gum, as I noticed that the rosin produced from the old and high faces was of an unusually good quality, grading from "I" to "M" instead of from "D" to "G," as in the United States. As to the relative yield of turpentine from a given quantity of crude, it is about the same in Mexico as in the United States."

In Mexico pack mules instead of wagons are used for transporting both the crude and the finished product.

Mexico exacts a high tariff on naval stores imported into that country. On turpentine, the duty is 15 cents per gallon in gold and on rosin $3.17 per barrel of 280 pounds. This tariff represents the difference in price between naval stores in Mexico and in the United States. There were in 1908 only eight stills in Mexico and the average capacity of each was small. The industry is little developed and as a consequence the local production is not sufficient to supply the demand. This makes importation of both turpentine and rosin necessary.

CHEMISTRY, AND THE CONSERVATION OF OUR WATER RESOURCES.

BY

PROFESSOR MARSTON TAYLOR BOGERT,

Columbia University, New York City.

[The author points out the important bearing that the purity of our water supply has upon its utilization for drinking purposes or in various industries, and the services of the chemist in determining its availability for these purposes. Attention is also called to the serious problem arising in connection with the steadily increasing pollution of our streams and tide-waters by sewage, factory waste and refuse of all kinds, and how chemistry can be of service in the solution of this problem.]

THE *quality*, as well as the quantity, of our water supply is a matter of grave concern. The purity of our drinking water is of vital interest to all of us, and it is to the chemist and bacteriologist that we must turn for assurances on this point. The character of the water used is also of very great moment in many industries.

The chief industrial use of water is for the production of steam; but if the water employed is rich in mineral salts, the formation of scale will proceed very rapidly. Hence, even in such a fundamental engineering operation as steam-power generation, the engineer must first consult the chemist as to the quality of the fuel and water to be used. In the United States, the average thickness of locomotive boiler scale is a sixteenth of an inch. This means a loss of at least 13 per cent. in fuel efficiency. For an eighth-inch scale, this amounts to 25 per cent., and for a half-inch scale, to 60 per cent. Taking one-sixteenth inch then as the average boiler scale, this means for our 51,000 locomotives a total annual loss which may be conservatively estimated at fifteen million tons of coal. The use of pure water in the boilers reduces coal consumption, and by decreasing the amount of repairs and prolonging the life of the boiler reduces also the demand for iron.

In those operations where pure water is indispensable, the cost of impure water is the cost of purification, and it is to the chemist that the manufacturer must turn for instructions as to

how this purification may best be accomplished. For some uses, as for boiler supply and paper making, the percentage of mineral matter is the chief concern; whereas, in such industries as brewing, distilling and ice manufacture, freedom from various micro-organisms must also be considered. Impure water means additional cost of production also to bleacheries, dye works, canning and pickle factories, creameries, abattoirs and packing houses, nitro-glycerin factories, woolen and strawboard mills, tanneries, chemical works, and factories for the manufacture of starch, sugar, glue and soap.

A serious problem arising in this connection is the steadily increasing pollution of our streams and tidewaters by sewage, factory waste, and refuse of all kinds. Practically all of our city and town sewage is disposed of in this way, together, often, with such other refuse as ashes, cinders, garbage and trash of every variety. In drainage and sewage there is considerable loss of valuable fertilizing materials, the annual loss in phosphorus alone being estimated as equivalent to 1,200,000 tons of phosphate rock. Few people have any idea of the vast amount of solid waste which must be regularly removed and disposed of in our great cities. In New York, excluding sewage, snow, street sweepings and dead animals, the solid refuse (mainly ashes, garbage and rubbish) amounts to over three million tons annually, or about 1450 pounds for every man, woman and child in that city. This huge amount if piled together would occupy over eight million cubic yards. The removal of that volume of earth, for example, would suffice to excavate a canal twenty-seven feet wide, ten feet deep and one hundred and fifty miles long; yet that volume of solid refuse must be handled every year by the New York Street Cleaning Department, in addition to the items excluded above.

Sawmills, pulp mills, wood-distilling plants, tanneries, starch factories, cheese factories, sugar refineries, gas works, chemical works, glass works, dye works, oil refineries, distilleries and breweries, smelters, mining plants, and many other industries, pollute the streams with their wastes until the once crystal-clear brook becomes a mixture of water, particles of wood, earth, dust, cinders, fat, oil, soap, coal, wool, hair, and refuse of all kinds, and different chemical ingredients and colors—a blue-black, sluggish fluid. The waste of sulphite pulp alone in the

United States is estimated at over one million tons a year, practically all of which finds its way into the streams, although it contains substances related to the sugars and the tannins which might be recovered with advantage.

Here is a most promising field for the chemist, and one in which he has already accomplished much. The manufacturer turns his waste into the stream for the same reason that the smelter allows his furnace gases to escape into the air—because he thinks that it is the cheapest thing to do. If the chemist can show him how he can make more money by saving these by-products and using them either for the production of heat and power or for the preparation of valuable commercial substances, he will no longer dump them into the stream.

The Water Supply Branch of the United States Geological Survey analyzes the river waters to ascertain their potability, their suitableness for manufacturing operations or irrigation, or in relation to soil erosion. Recently, in co-operation with the Rhode Island State Board of Health, it has been making an investigation of various factory wastes now polluting the streams, and it has been found not only that all those so far studied can be satisfactorily purified at a reasonable expense, but also that in many cases it can be accomplished with substantial profit.

The poisoning of our streams and coastal waters also affects that portion of our food supply derived from these sources, by either killing off all fish and mollusca, or rendering them unfit for food. Brooks in the coal mining regions, once well stocked with fish, have become blackened mine drains, in which life of any kind is impossible. Although we are annually planting probably six billion fry in our inland and coastal waters, an amount greater than all the rest of the world put together, those best qualified to judge state that the maintenance of fish life in this country is fast becoming impossible. Hence, if the chemist can bring about a reduction of this pollution, he will be assisting directly in preventing the loss of this food supply, to say nothing of the debt of gratitude which all the disciples of Izaak Walton will owe him. It should not be forgotten further that fish supply us also with oil and fertilizer material, as well as with substitutes for isinglass, gelatin and glue.

Although approximately two-thirds of the surface of our globe is covered with water, less than 5 per cent. of our food

supply is drawn from the sea. As it seems not unlikely that by 1950 the population of the United States will be at least two hundred million, the possibility of the seas contributing more largely to our support is worth considering.

Professor Bonnycastle Dale predicts that seaweed will some day be largely used for human food. Seaweeds have, to be sure, been used as food for ages, and in certain parts of the Orient constitute staple articles of diet, but the actual amount so used is at present relatively small. It has been calculated that enough proteids are lost annually in the decay of seaweeds on the sea beaches of the United States to take the place of the total product of our Northwestern wheat fields. In the great Sargasso Sea sufficient nutritious vegetation flourishes and decays to support the entire population of Europe, if harvested and prepared in a form suitable for human consumption.

Thirty per cent. of our horsepower now used is used electrically. At the present rate, it will equal or exceed power mechanically applied by the year 1920. As has been said before, we are entering the age of electricity, which means the age of water-power and the age of electrochemistry. The electrification of our railroads will result in the disappearance of one of the most frequent sources of forest fires—hot cinders from locomotive stacks.

Chemistry's services in the field of irrigation include the furnishing of the necessary explosives for rock blasting, cement and concrete for the dams, the analysis of the water, and the determination of the kind of fertilizers needed on lands reclaimed. The Bureau of Soils of the Department of Agriculture has been investigating the availability of mine runnings, and various waste waters, for irrigation.

GROWTH OF GAS-PRODUCER POWER PLANTS.

REPORT BY THE UNITED STATES GEOLOGICAL SURVEY.

More than 500 gas-producer power plants, ranging in size from 15 to 6000 horsepower, are now in operation in the United States. About 88 per cent. of these plants are running on anthracite coal, a few on anthracite or coke, and the remainder on bituminous coal and lignite. In a bulletin on the recent development of the gas-producer power plant in the United States (Bulletin 416), just issued by the United States Geological Survey, R. H. Fernald, consulting engineer, states that the internal-combustion engine has already become a serious rival of the steam-engine in many of its applications, and that the development of the large gas engine within the last few years has been extremely rapid. Only nine years ago a 600-

horsepower engine exhibited at the Paris Exposition was regarded as a wonder, but to-day four-cycle, twin-tandem, double-acting engines of 2000 to 3500 horsepower can be found in nearly all well-equipped steel plants, and some plants in this country contain several units rated at 5400 horsepower each.

RAPID DEVELOPMENT OF THE GAS ENGINE.

This rapid advancement of the large gas engine was made possible by improvements in the production of cheap gas directly from fuel by means of the gas producer. A few scattered gas-producer plants were installed for power production in the United States before 1900, but the application of engines of this type to the production of power in any general sense has been developed since that date. During the first few years of this period of development anthracite coal, coke, and charcoal were used almost exclusively. It remained for the United States Geological Survey, in its testing plants at St. Louis and Norfolk, to demonstrate the possibility of using in such plants practically all grades of fuel of any commercial value, without reference to the amount of sulphur or tarry matter they contain.

TESTS MADE BY THE GEOLOGICAL SURVEY.

The tests made by the Survey, 168 in all, included 138 on bituminous coals, 9 on subbituminous coals, 10 on lignite, and 11 on miscellaneous fuel. The average consumption of fuel for a brake-horsepower hour was 1.36 pounds of bituminous coal, or 1.99 pounds of lignitic coal, the minimum consumption being 0.84 pound and 1.48 pounds, respectively. Comparative tests of 75 bituminous coals under a water-tube boiler and in the gas producer showed that the average fuel consumption per brake horsepower in the steam plant was 2.7 times that in the producer plant. Several low-grade coals and lignites that were of little value, or even worthless under the steam boiler gave excellent results in the producer. Other low-grade fuels—such as roof slabs, culm, and washery refuse, and even a bone coal that contained 44 per cent. of ash—have been used to advantage in the producer under proper commercial conditions.

PRESENT STATUS OF GAS-PRODUCER PLANTS.

Professor Fernald solicited the views of the principal manufactures of gas producers on the present status of the gas producer as a source of power, with particular reference to the special conditions that oppose or make for its introduction. In addition, he or his assistant, C. D. Smith, personally visited 69 different plants that furnish power for a great variety of purposes, to determine the economy and reliability of the plants under average conditions. After this inspection Professor Fernald decided:

1. That the plants as a whole are giving remarkable satisfaction in view of the brief period of development.

2. That the most serious difficulty seems to arise from the lack of competent operators to run the plants, though there are many more competent operators to-day than three years ago.

3. That the situation regarding misrepresentations and misunderstandings resulting from incompetent salesmen has with the stronger companies greatly improved.

4. That the situation regarding trouble due to manufacturers neglecting plants that have been installed and paid for has changed decidedly for the better within the last few years.

The bulletin, which contains charts showing the growth of producer-gas plants and the location of the plants now in operation, may be had free of cost by applying to the Director, United States Geological Survey, Washington, D. C.

INCIDENTAL PROBLEMS IN GAS-PRODUCER TESTS.

REPORT BY THE GEOLOGICAL SURVEY.

As part of its investigation of methods for increasing the efficiency of fuel resources, the United States Geological Survey is studying the general problems involved in the economic use of fuels in gas producers. Among many incidental problems of prime importance that have arisen in the course of this study are those of determining, under practically constant conditions, the duration of gas-producer tests necessary to reduce the possible error to a minimum and of determining the differences of temperature in the fuel bed of the gas producer and the influence of such differences on the chemical reactions taking place within the producer.

In attempts to improve the gas producer considerable attention has been given by manufacturers to such problems as those of fixing or isolating the combustible components of the tar, utilizing the waste heat of the producer for the generation of the steam required by the plant, and applying the suction principle to bituminous coal and other tarry fuels. Little study, apparently, has been given to the physical and chemical conditions most suitable to the formation of hydrogen and of carbon monoxide, with a view to regulating the percentages of these gases in generators using fuels other than anthracite coal or charcoal.

Reports on the two problems first stated above are given in Survey Bulletin 393, which can be obtained free of charge by applying to the Director of the Survey at Washington.

The bulletin consists of two papers, one, by R. H. Fernald and C. D. Smith, on the factors affecting the proper length of tests, the other, by J. K. Clement and H. A. Grine, on temperature differences in the fuel bed.

Messrs. Fernald and Smith, summarizing the results of their experiments, state—

"That throughout a test the fuel bed should be maintained in uniform condition, with regard to both the character of the fire and the thickness of the bed.

"That failing in this, special care should be exercised to see that the fuel bed is in the same condition and of the same thickness at the close of a complete test, or end of a test period, as at the beginning.

"That a test should never be started when the producer has been standing idle for some time with 'banked fires,' as the fuel bed will not be in the average condition under which it will be required to work during the test.

"That if, as the appointed hour for closing the test approaches, the fuel bed is not in the proper condition, the time of closing the test should be postponed until the bed naturally assumes the proper thickness and character. No forcing of conditions should be allowed simply to bring the test to an end at a previously determined hour."

Messrs. Clement and Grine report that—

"Temperature observations were made and gas samples taken in different parts of the fuel bed of the gas producers. The temperature was found to be highest at the bottom of the fuel bed and to decrease from this point to the top of the bed.

"The temperature of the inner region of the fuel bed was found to be 300° or 400° lower than that of the outer layers. A corresponding inferiority in the quality of the gas in the center of the producer could not be established; probably on account of the defective method of sampling.

"It has been suggested that by an improvement in the method of admitting the draft to the fuel bed a more uniform distribution of temperature, and consequently a gain in the capacity of the producer and in the quality of the gas, might be obtained.

"Reference has been made to recent experiments by one of the authors which have established 1300° C. as the lower limit of temperature for the formation of a gas rich in CO."

MECHANICAL AND ENGINEERING SECTION

(*Stated Meeting, held Thursday, March 17, 1910.*)

A NEW PYROMETER.

BY

CHARLES E. FOSTER.

[The Radiation Pyrometer has great advantages over other types when the temperature to be measured is very high. The "total radiation" instrument is preferable to the purely optical pyrometer for industrial work. Instruments hitherto made, belonging to the "total radiation" class, have needed accurate focusing in use or have been relatively inefficient. The new type described herein does not require focusing in use but still is efficient enough to be robust and rapid in action. The practical effect of the situation and surface of the hot body upon reading is discussed, and methods are indicated by which accuracy may be obtained.]

As a broad proposition it is hardly necessary to insist upon the need for pyrometers in the control of heating processes. Since prehistoric times, heat has been applied to produce change or destruction in materials under manufacture. This tendency of heat to produce change is a source of trouble when the design of a pyrometer is considered. The heat must change the nature of some part of the material manufactured, but in order to be continually reliable the pyrometer must not be subject to change as the result of the heat. Those pyrometers in which a part of the instrument is raised to the actual temperature to be measured must therefore have very definite upper temperature limits, and their life will be very short when used at high temperatures.

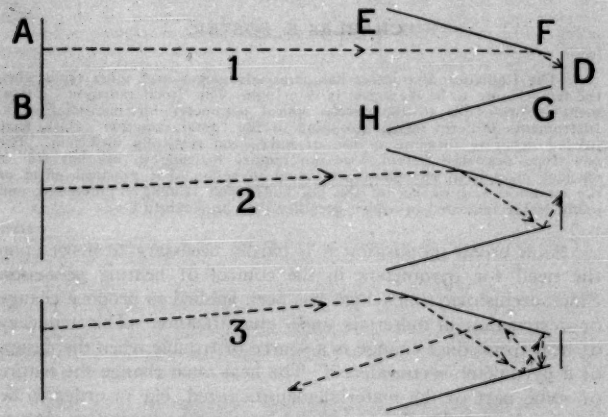
These considerations have called into existence a class of instruments broadly known as radiation pyrometers. A radiation pyrometer can be used at the highest temperatures attainable because no part of it is subjected to the actual temperature measured; it works entirely at a distance.

Radiation instruments may be divided into two main classes: first, those in which the measurement is made by means of the luminous radiation (these are called optical pyrometers), and

secondly, those in which the whole of the heat radiation is used, these being known for distinction as total radiation instruments. It is the latter class only which will be considered here.

For general information on the subject of radiation pyrometry, I cannot do better than refer to the translation, by G. K. Burgess, of Le Chatelier's book, "High Temperature Measurements." * In this book also will be found much information on the early history of radiation pyrometry. There are, however,

FIG. 1.



two applications of radiation methods which, I believe, are not there mentioned, but which are of some structural interest.

Melloni, in his apparatus for study of the laws of radiant energy, used a conical reflector to concentrate the heat rays emanating from the hot body, and near the apex of the conical reflector, a thermopile as the sensitive body. Fig. 1 shows such an arrangement diagrammatically.

The line *AB* represents the surface of the hot body. *EFGH* is the conical reflector and *D* the sensitive surface of the thermopile. It will be seen that the use of a conical reflector involves the possibility of multiple reflections. A heat ray such as 1

* High Temperature Measurements, by H. E. Le Chatelier and O. Boudouard, translated by G. K. Burgess.

reaches the thermopile after a single reflection, while one such as 2 suffers double reflection. In the case of 3 the ray never reaches the apex at all.

From this it is evident that a conical reflector may be a very inefficient heat concentrator. At each reflection the ray loses a fraction of its energy due to absorption and dispersion. Some of the heat absorbed by the reflector is conducted towards the apex of the cone and it is there radiated directly on to the thermopile. This heat conduction will take time and consequently, though it will add slightly to the total efficiency of the reflector, it has the great practical disadvantage of making the thermopile slow to reach a maximum and slow also to cool down again.

A second historical item is due to H. L. Callendar. In this case there is no heat concentration. The sensitive device is a pair of grids of platinum wire. These are enclosed in a glass vessel from which the air is partly exhausted. One grid is blackened while the other is left bright. When radiant heat falls on such a device the blackened grid will absorb more heat and will get hotter than the bright grid. The difference of temperature will be accompanied by a corresponding difference in electrical resistance which may be measured with a Wheatstone Bridge. This device, which is similar in principle to the Langley Bolometer, has been applied to the measurement of solar radiation. H. L. Callendar described its use on a furnace in his U. S. Patent of 1898.

The history of the radiation pyrometer is brought down to about 1904 by G. K. Burgess and includes the description of C. Fery's pyrometer. This instrument is well known in metallurgical work, and need not therefore be fully described here. It is sufficient to say that it is a reflecting telescope with a thermocouple junction at the focus. In order to render this instrument available at different distances it has an eyepiece and a pair of subsidiary mirrors to guide the user in focusing it.

Undoubtedly the Fery Pyrometer was the first practical total radiation instrument. The heat concentrator is a concave mirror, gilded on the face. It is very efficient for the following reasons:

1. Each heat ray suffers only a single reflection.
2. Glass allows high polish of surface.
3. The gilding gives the highest reflecting power, particularly for the invisible heat waves.
4. The focus is definite, giving a high degree of concentration.

For these reasons the Fery Pyrometer can be used where the hot body is small or the working distance great. The necessity for the eyepiece and focusing mirrors adds, of course, to the cost in manufacture and calibration.

In 1907 C. B. Thwing designed a radiation pyrometer having a long cylindrical casing with an opening at the end presented to the hot body. At the other end was a conical reflector and thermopile similar to that used by Melloni. This design obviated the necessity for focusing since a conical reflector of this kind has no definite focus. It has, unfortunately, the disadvantage of low efficiency and sluggishness, probably due to the multiple reflection mentioned previously.

It is here worth remarking that the indications of such pyrometers as Fery's or Thwing's are read on a millivoltmeter which measures the electromotive force set up in the thermocouple or thermopile. This being so, the lower the efficiency of the receiving part the more sensitive must be the millivoltmeter. Sensitiveness in a millivoltmeter is generally accompanied by delicacy and high cost, therefore high efficiency in the receiving portion is very much to be desired.

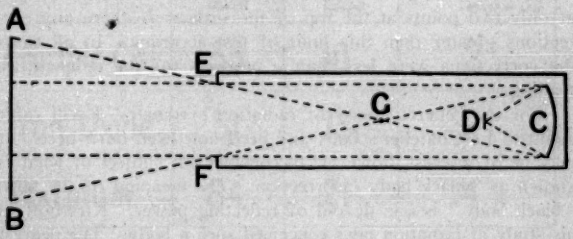
About the same time, 1907, C. Fery introduced a modification of his pyrometer. The thermocouple junction was replaced by a very small bimetallic spiral as the sensitive body at the focus of the concave mirror. This spiral was made of two metals of different coefficients of expansion so that, when heated by the focused radiation, it uncurled. A very light pointer attached to the spiral rendered the uncurling visible on a scale calibrated in temperature.

The gilded concave mirror is a desirable point because of its high efficiency, while the focusing mechanism is at times a disadvantage, particularly when the instrument has to be put into unskilled hands. To take advantage of the first property and avoid the second I designed the arrangement shown in Fig. 2.

The casing has at one end an aperture *EF*. At the opposite end is a gilded concave mirror *C*. One of a pair of conjugate foci of the mirror is at the aperture *EF* while the other is on the sensitive device *D*. Therefore there will be thrown on *D* a focused image of the aperture *EF*. Since the relative positions of these three essential parts are fixed, there is no focusing

needed in use. For this reason it has been called the "Fixed Focus Pyrometer." The only condition that must be satisfied is that the aperture, as seen from every point of the mirror surface, must be filled by the hot body under test. This condition is satisfied if the hot body coincides with or overlaps any section of the cone *GAB* or any extension thereof. In the instrument on the table the position of the apex *G* is marked by the centre ring. The directions for use are, then, that the distance from the hot body to the centre ring must not exceed a certain constant multiple of the smallest dimension of the hot body. In the case here the multiple is ten, that is to say, with a hot body whose diameter or other smallest dimension is 6 inches, the working distance, as measured from its surface to

Fig. 2.



the centre ring, must not be more than 60 inches. Any smaller working distance will not alter the reading, provided the body is uniformly heated. The only result of bringing the hot body *AB* closer would be that its outer edges would be out of the measurement, consequently the user is not called upon for accurate judgment or measurement of distance.

For work on extremely high temperatures the proportions of the cone *GAB* can be altered so as to allow working at greater distances.

In the example here shown the sensitive device is a very small thermocouple. The heating of the junction where the two elements are joined together by the focused radiation generates an electromotive force, and this, or rather the resulting current, is read on a suitably calibrated milliameter. The calibration is made direct reading in temperature.

It is interesting to note that without involving inconvenient dimensions the electromotive force developed at 2400° F. exceeds that which would be given by a Le Chatelier thermocouple inserted directly into a furnace at that temperature. Since the thermocouple in the receiving tube is of low and constant resistance the rest of the circuit may also be of low resistance. This allows the use of an indicating instrument of very robust construction. Another advantage of this type of instrument is that the mirror in the receiving tube is well protected from dust and fumes because it is situated at the bottom of a long closed tube.

As indicating the order of accuracy to be expected, a certificate issued by the Bureau of Standards, Washington, may be quoted. The instrument tested was one of the first of this type made and no unusual care was taken in its calibration. The results were given to an accuracy of the nearest 20° F. and at only two points at the top of the scale were there any corrections greater than this limit of test accuracy. In all cases the corrections were less than 2 per cent. of the temperature reading.

For the general theory of radiation pyrometry, I will refer again to Le Chatelier's book and need not dwell on it here. It may be of interest, however, to consider the subject of what is known as "black body" correction. The meaning of the term "black body" is one devoid of reflecting power. Kirschoff in his study of radiation laws conceived such a body. The nearest experimental realization is the inside of a uniformly heated space as viewed through a comparatively small opening. An alternative realization of the "black body" would be one out in the open whose surface is quite without reflecting power. An ordinary furnace viewed through a small door or peep-hole will give a very close realization of Kirschoff's "black body." Again, many substances met with in practical manufacturing give fairly close approach to the same conditions.

The bearing of these theoretical considerations on the practical application of a radiation pyrometer is as follows. If the hot body is out in the open and its surface has appreciable reflecting power the radiant energy it gives out will be less than that of a theoretical "black body." The higher the reflecting power the greater will be the difference in reading on a radiation pyrometer.

At first glance this consideration appears to put serious limitations on the use of radiation methods. Happily this is not so in practice.

In the first place, no matter how large the departure from the true black body, the energy emitted by the hot body will bear a definite relation to the true temperature when the conditions

FIG. 3.

Corrections, in degrees, to be added to "black body" temperature of 1000°C

Surface	→	→	→
Crucible Clay	38	10	2
Iron Oxide	51	13	2
Platinum	84	21	4

are constant. Therefore, the readings of the pyrometer will be consistent and serve quite well to define the temperature. It is consequently evident that the indicating instrument can be specially calibrated to read true temperatures for any defined conditions of use, and this is very often done successfully in practice.

In the second place, as stated previously, the interior of a furnace that is fairly uniformly heated will realize the "black body" very closely. Since so many manufacturing processes call for the measurement of the temperature inside furnaces, the ordinary calibration for a radiation pyrometer is made on the assumption that it is to be used on a "black body." It is here important to remark that the optical pyrometer is in the same case with the total radiation instrument in this connection.

With a view to showing the order of magnitude of the black body correction under different conditions, and with different

substances, I have made a few calculations. I do not claim very high accuracy for the numerical corrections employed but I believe them, at any rate, to be close enough for practical purposes.

I have taken three substances, crucible clay, iron oxide and polished platinum. I have then assumed each to be exposed, first out in the open, next in a shallow uniformly heated recess, of which the depth was half the diameter, and lastly in a deeper recess, also uniformly heated, whose depth was one and a half times its diameter.

The formula used in the calculations has shown itself to be at least approximately true.

$$T_2 - t_2 = t_2 \left\{ \frac{T_1}{t_1} - 1 \right\} \left\{ \frac{A}{180} \right\}^2$$

T_1 is the true temperature of a hot body when its black body reading is t_1. T_2 is the required true temperature for a black body reading t_2. A is the angle in degrees subtended by the opening in the recess from any point on the surface of the radiating body.

The temperatures in the formula should be absolute temperatures and the difference between T_1 and T_2 should not be very large. However, the result of applying the formula to 1000° C., using the correction derived from 700° C., does not introduce a serious error.

The results have been worked out to the nearest whole degree, and are shown in Fig. 3. It will be seen that placing the body in even a shallow recess reduces the correction very largely, while in a deep recess the correction becomes practically negligible. A furnace, even with the door wide open, gives conditions as good as those in the third case.

Fig. 3 shows that crucible clay gives a better approach to black body than iron oxide, a result that is, at first sight, surprising. I believe a possible explanation may be found in the second condition assumed in the table. If the surface of the clay is examined under the microscope it will be found to have a more or less granular structure. Though each crystal is highly reflecting, the surface as a whole will consist of an aggregation of recesses, having roughly the proportions of the second case, and would therefore collectively act as a fairly good black body.

SECTION OF PHOTOGRAPHY AND MICROSCOPY

MODERN PHOTOGRAPHIC DEVELOPMENTS.

BY

JOHN BARTLETT,

Editor of Bulletin of Photography.

INTRODUCTORY ADDRESS TO THE SYMPOSIUM ON MODERN PHOTOGRAPHIC DEVELOPERS, DELIVERED AT STATED MEETING HELD THURSDAY, FEBRUARY 24, 1910.

IT sounds like a photographic truism to say,—"the perfect negative is the outcome of proper adaptation of developer to the character of the exposure." True, if the time has been correctly estimated and the developer tempered thereto, anyone may work out a plate's salvation without fear or trembling, but when the personal equation of under- or over-exposure is taken into consideration, the evolution of the *perfect* becomes really a fine art and then fore-knowledge and experience are demanded if one looks for softness, without smear, high-lights distinct and well defined without harshness, and shadows rich and full of detail, going by imperceptible gradations into the lights.

How shall all this be accomplished? How this fine adjustment acquired? I suppose it is the desire to understand what perfect development means, which has stimulated this Symposium on development by the members of this Section.

Without going into detail as to the chemical nature of development of the latent image, which would be out of place in a mere introduction to the subject, and more effectively considered by a concensus of opinion, I would like to say that I have often thought we do not fully appreciate the resources we have in our phalanx of modern developers. Our pyro, our metol, amidol, hydroquinone, ikonogen, etc. We know a good deal about their action, but do not always take advantage of their specific value.

Pyro, which seems to have taken something of a back seat, I have found still a most faithful ally in many difficult cases, especially for obtaining plucky, vigorous negatives, or where a very dilute developer is requisite.

Pyro, unlike most of the other agents of development still works energetically when the minimum quantity is in solution, and seems capable of accomplishing the same results as when concentrated. The difference being only a question of time. It is for this very reason that it is most valuable in the so-called tank-development. But there are cases where the other agents have decided advantage over pyro and it would be unwise to cling to it and seek compensation for its shortcomings by modification of the other constituents of the developing solution.

Suppose we wish to develop an exposure in which we have certain colors which unequally affect the sensitive film such as blue and yellow and red in conjunction. That is we want to equalize as much as possible the imperfect action of the light as far as color rendition is concerned.

It certainly would be unwise in such a case to employ a strong acting developer but more judicious to look for such an agent or combination of agents as would have a tendency to give more harmonious relations. Glycin and metol are mild, yet penetrating, but the trouble is most of us are apt to discard anything that is not of the seven-leagued-boot variety so that we get over the ground in a trice.

The advantage of glycin over pyro, with short exposures, is that it gives less dense high-lights and richer shadows, that its action being slower it equalizes better the distribution of light and shade.

We have a means of increasing the contrast in a glycin developer by judicious application of a second developer such as hydroquinone. The practice of employing mixed developers is excellent but little indulged in, yet it enables one to better control final results. It is foolish to adopt a certain constituted developer and make it applicable to all sorts and conditions of things, however great the endorsements.

Some combinations, it is true, have a rather wide field of application but it is safest to study the character of your illumination and to adjust the special developer to it. Recently I encountered a batch of plates which would work flat do what I would with them and were also liable to fog with prolonged development. Here, strange to say, nothing worked so well as the antiquated ferrous oxalate. It gave clean, rather brilliant results, marvellous when compared with those I had evolved with the more recent reagents. So you see we cannot even afford to relegate this old fossil as yet to the limbo of desuetude.

Development I might say is really a fine art. There are so many factors involved in the problem both before the plate is submitted to the developer as well as during the process of evolution of the image that one hardly has a right to lay down certain fixed rules for the accomplishment.

One of these factors is temperature, but we will go no further here into the subject as this suffices by way of introduction.

A PRIMER ON EXPLOSIVES.

COAL MINER'S MANUAL ISSUED BY THE GEOLOGICAL SURVEY.

In continuance of its efforts to reduce the number of fatal accidents in American coal mines, the United States Geological Survey has just issued a primer for the benefit of miners and others who have anything to do with explosives.

DANGEROUS EXPLOSIVES.

The improper use of explosives in coal mines is doubtless the cause of many deaths that are attributed to other agencies. Vigorous objection is made to the use of black powder in any mine where there is danger of a gas or coal-dust explosion. The operators and miners in such mines are urged to use explosives that have been tested at the Survey's mine accidents station at Pittsburg, Pa., and placed on the "permissible" list

INCREASING USE OF EXPLOSIVES.

The use of explosives is increasing both in quantity and in the variety of purposes to which they are applied. They are now made at 150 plants in different parts of the country, and the product of a single year is now nearly 500,000,000 pounds. Of all this material no explosive is safe in the hands of a careless or ignorant person, whether it is used in mining or otherwise. Statistics recently compiled by the Railway Bureau for the Safe Transportation of Explosives show that more than 400 persons have been killed or injured and over $3,000,000 worth of property destroyed by explosives in transit by rail. The fact that three years of co-operative effort under the supervision of this bureau have reduced these losses to almost nothing should encourage the hope that similar co-operative effort may likewise greatly reduce losses of life and property from the use of explosives in mining.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, April 20, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 20, 1910.

MR. LOUIS E. LEVY, *Temporary Chairman.*

Additions to membership, 19.

Dr. J. A. Holmes, Chief of the Technologic Branch of the United States Geological Survey, addressed the Meeting on the subject of "The Waste of Life and Resources in the Mining Industry."

The speaker described briefly the rapid growth of mining in the United States as a fundamental part or basis of the varied industries and commerce of the country. He called attention to important facts illustrating the waste of resources in connection with our methods of mining and use of important mineral resources; and discussed the loss of life resulting from the increase of mine accidents in all parts of the country, and the mining conditions which tend to increase both the loss of life and the loss of resources.

The subject was illustrated by numerous lantern slides and specimens of mine appliances.

At the close of the address a brief discussion ensued in which Dr. Goldsmith, Dr. Chance, the Speaker and Chairman took part.

On motion, duly seconded, a vote of thanks was tendered Dr. Holmes for his interesting remarks and the paper was referred to the Committee on Publications. Adjourned.

R. B. OWENS,
Secretary.

ELECTIONS TO MEMBERSHIP.

At the stated meeting of the Board of Managers held Wednesday, April 13, 1910, the following gentlemen were elected to membership:

Life Members.—Mr. Charles Day, 608 Chestnut St., Phila.; Mr. Kern Dodge, 608 Chestnut St., Phila.

Resident Members.—Mr. W. Bruce Barrow, real estate broker, 130 North Twelfth St., Phila.; Mr. J. Clifford Brooks, electrical engineer, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. Ralph K. Burgess, Jr., 55 North Second St., Phila.; Mr. Harold Calvert, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. Howard T. Deshong, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. George Ross Green, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. Arthur B. Huey, Esq., lawyer, Commonwealth Trust Building, Phila.; Mr. Horace P. Liversidge, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. William F. Lloyd, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. Joseph B. McCall, President Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. E. F. Mason, Inspector Motive Department P. R. R., Broad Street Station, Phila.; Mr. William G. Rogers, Philadelphia Electric Company, Twenty-eighth and Christian Sts., Phila.; Mr. Louis C. Smith, Philadelphia Electric Company, 122 Arch St., Phila.; Mr. J. W. Sylvester, Philadelphia Electric Company, Tenth and Chestnut Sts., Phila.; Mr. Wilson Woelpper, banker, 119 South Fourth St., Phila.

Non-resident Members.—Mr. Guy E. Norwood, industrial engineer, Diamond Rubber Co., Arkon, Ohio.

Associate Members.—Mr. John K. Class, draftsman, 330 Benson St., Camden, N. J.

COMMITTEE ON SCIENCE & THE ARTS

(*Proceedings of the Stated Meeting, held Wednesday, April 6, 1910.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 6, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following report was presented for final action:
(No. 2459) Automatic Telephony, Automatic Electric Company, Chicago. (Adopted, Elliott Cresson Award.)
The following reports were presented for first reading:
(No. 2462) Shaft Couplings, Shaft and Hub Connections, E. A. Blanton, Jr.
(No. 2487) Bakelite, Dr. Leo H. Baekeland.

THE ANALYSIS OF ROCKS.

REPORT BY THE GEOLOGICAL SURVEY.

The chemical work of the United States Geological Survey has long commanded the general attention of workers in inorganic chemistry at home and abroad, and many of the reports of the Survey's chemists have become reference works in colleges and universities. One of the Survey's chemical bulletins (Bulletin 305), on the analysis of silicate and carbonate rocks, by W. F. Hillebrand, has been translated and republished in Germany, and the home and foreign demand for it has completely exhausted the edition printed. A new and revised edition of this manual, numbered Bulletin 422, has therefore just been published by the Survey. Dr. Hillebrand, the author, was for 28 years one of the Survey's chemists and is now chief chemist of the Bureau of Standards of the Department of Commeree and Labor.

COVERS THE EARTH.

The two classes of rocks considered form the bulk of the earth's crust, and although the bulletin was not prepared primarily for economic purposes the methods and principles described may be applied directly to economic work. The rocks of these two classes contain many valuable metals and minerals.

THOROUGH WORK DEMANDED.

The importance of complete and thorough analysis is especially emphasized; and in this connection it may be noted that the Geological Survey's analytical work is distinguished for its thoroughness. The geologist's demands on the chemist have become more exacting as he has learned to realize the need of more thorough work, and the geologic chemist has not only kept pace with the demand but has himself indicated to the petrographer the importance of better analyses. The standard of accuracy has been thus raised and maintained.

The bulletin contains 239 pages and is illustrated by 27 cuts showing forms of apparatus. It may be obtained without charge by applying to the Director of the Survey at Washington.

ANNUAL REPORT OF THE SCHOOLS FOR THE SESSIONS OF 1909-10.

THE results obtained in the schools this season have been excellent, due to the ability and efficiency of the staff of instructors and to their harmonious working to maintain a logical sequence and cumulative effect. This is difficult in a night school, where applicants of very different abilities and experiences are received at any time, but it has been accomplished with a remarkable degree of success, and we believe that a much larger proportion of the total number of students receive valuable benefit here than in most institutions of the kind.

The course in Geometric, Isometric and Machine Drawing, Mathematics, Strength of Materials, and Machine Design is very complete and requires time and considerable hard work, but serious students, who really mean to profit by this opportunity for an engineering education, should take all the branches in the order named.

The course in Architectural Drawing is of great use to those connected with the building trades and is thoroughly practical and complete in itself.

The course in Free-Hand Drawing is intended for decorators, illustrators, designers, and art beginners, and is complete in itself.

The course in Naval Architecture, although highly specialized, should be well patronized in this centre of ship-building, but before entering it applicants should take the same course in mathematics which is preliminary to machine design, unless they are already pretty well versed in it.

The real merit of this school should be better known and understood, for it stands upon this alone, and receives very little benefit from advertising, exploitation, or publicity agencies of any kind.

WILLIAM H. THORNE, *Director.*

SCHOOL OF MECHANICAL DRAWING.

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

In the Senior Mechanical Class,

William Meinel,	Ernest Lindgren,	Walter L. Bower,
Clarence H. Smythe,	William S. Bardsley,	Joseph Kampman.
Ernest Baumer,	Gustav Heinecke,	

In the Intermediate Mechanical Class,

John Dawson,	Watkins F. Mintzer,	Harry Haman.
Howell J. Floyd,	John Foley,	
William H. Armstrong,	Julius Metzer,	

In the Junior Mechanical Class,

Malcolm V. D. Remington,	William Steel.

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND, ENTITLING THEM TO TICKETS FOR THE NEXT TERM:

William S. Bardsley,	Malcolm V. D. Remington,	Charles W. Weber.
Walter L. Bower,	Ara S. Pennewell,	C. Nelson Rocholl.
Howell J. Floyd,	William Steel,	

THE FOLLOWING STUDENTS, HAVING COMPLETED A FULL COURSE WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES:

Mechanical Drawing,	*Architectural and Free-Hand Drawing*
William Meinel,	Ara S. Pennewell,
Clarence H. Smythe,	C. Nelson Rocholl,
Ernest Baumer,	Howard G. Tomlinson,
Gustav Heinecke,	Edward E. Ellis,
Joseph Kampman,	Arnold Muller,
Thomas J. Devine,	John E. Sharp,
John Henry Gross,	Stanley K. Weber,
	Charles W. Weber,
	George S. Keichline.

SCHOOL OF ARCHITECTURAL AND FREE-HAND DRAWING.

The work this year has been of great service to the students. Nearly all in the *Architectural* class have been actually at work in various branches of building construction and their progress in the theoretical, artistic, and technical features has been excellent. The advance and improvement of those in the *Free-Hand* class have likewise been very flattering, as specially shown by the designs for gas-fixtures made by one of them.

CLEMENT REMINGTON, *Principal.*

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

In the Architectural Class,

Ara S. Pennewell,	Arnold Muller,	John E. Sharp,
C. Nelson Rocholl,	Edward E. Ellis,	Stanley K. Weber,
G. Howard Tomlinson,	Samuel L. Amey,	

In the Free-Hand Class,

Charles W. Weber, Karl W. Stadon.

SCHOOL OF MATHEMATICS AND MACHINE DESIGN.

During this session the aim has been to devote particular attention to those topics which present the greatest difficulty, depending upon the student's unaided effort to master the more elementary features and, thus, effect not only economy of time in covering a given field but also increase the value of the instruction by this incidental introduction of the "self-help" feature.

The regularity of attendance and the enthusiasm displayed are gratifying features of this year's classes. This is due to the very efficient coöperation of Mr. John Loman who conducts the class in algebra and of Mr. H. E. Hutchins who has charge of the class in trigonometry. To both these gentlemen my best thanks are due for their unsparing effort in improving the efficiency of the course.

LUCIEN E. PICOLET, *Principal.*

THE FOLLOWING STUDENTS, HAVING COMPLETED THE REQUIREMENTS OF A FULL COURSE, ARE AWARDED CERTIFICATES:

Lautaro V. Dale, H. A. Kaupp,
Charles Hubsch, Gerald J. Oldroyd,
Edward C. Pladder.

SCHOOL OF NAVAL ARCHITECTURE.

The session just closed has been productive of very encouraging results. The number of students has exceeded the average of recent years. There would have been a still further increase if it had not been considered advisable to reject several prospective students because of inadequate preliminary training. Past experience has shown that students, deficient in the elementary principles of mathematics, should not undertake the study of naval architecture.

Contrary to the usual experience in evening classes, the regularity in attendance has been very satisfactory. This is indicative of the sincere efforts which the majority of the students are making.

The Institute is again indebted to the generosity of Mr. Clement A. Griscom for an excellent set of drawing instruments, which in accordance with the usual custom will be awarded as a prize for scholarship and regular attendance. Mr. Griscom has on many former occasions manifested his interest in the work of the Institute, in elevating the standard of shipyard employees by preparing them to perform their duties more effectively.

There will be no graduates this year. It so happened that all the students, taking this course last year, completed the prescribed amount of work and were graduated. Several of these enrolled again last September to take up post-graduate work.

M. H. KEIL, *Principal.*

FOREST RESOURCES OF SOUTH AMERICA.

The forests of South America are principally tropical, but in the Andes Mountains and the southern end of the continent are found forests of a temperate and sub-arctic character resembling somewhat those of the United States and Canada

The tropical forests are totally different from our north woods. There are no solid stands of single species or even of a few mixed species. Instead, hundreds of kinds of trees grow thoroughly mixed and scattered through the whole forest. This is one of several reasons that makes logging in tropical forests so expensive and often unprofitable.

Rubber hunters have explored nearly the whole tropical forest in search of that necessary article of commerce, but aside from that South American forests have only been cut into for a few miles back from the coast and the principal ports and drivers. Even in this area only the species at present most valuable for commerce have been thus far cut, for example, cedar, mahogany, rosewood, lignum-vitæ, fustic, and ironwood. Railroads, where they exist, charge such exorbitant freight rates that they have not much encouraged exploitation of the forests. In addition to this, the sparsity of population and lack of labor have also retarded development of the forests.

Most of the woods growing in these tropical forests are very heavy, hard, and rich in color. Greenheart is so hard that it nicks the axes of the choppers and will last for over one hundred years in water. It should be noted here that the style of axe used in the tropics is quite different from our common north woods axe and has a very narrow bit. The American broad-bitted axes would be very ineffective on such hard woods.

Growth is so luxuriant and rapid that ruins or abandoned farms are promptly covered with a dense young growth of trees and vines that in a few years obscures the marks of civilization. The great forest of the Amazon basin is eleven hundred miles long east and west by seven hundred and fifty miles north and south. It covers nearly a million square miles in Brazil. But as it lacks construction timbers it cannot be looked to for relief from the approaching scarcity in that kind of wood.

Lumber is not so extensively used in construction of homes as with us. Brick, stone, mud, and tiles are extensively used, also bamboo, palm, etc.

SECTIONS

Electrical Section.—A meeting of the Section was held on Thursday evening, March 31, at eight o'clock. Mr. Thomas Spencer in the Chair. Forty-three members and visitors present.

After the reading of the minutes of the previous meeting the Chairman introduced Mr. John Meyer, Commercial Engineer, Philadelphia Electric Company, who presented a communication on the "Electric Vehicle." The speaker confined his remarks to pleasure carriages and illustrated the subject with numerous lantern slides.

The thanks of the meeting were extended to the speaker for his interesting paper.

During the discussion which followed Mr. Harry G. Morris described an electric vehicle which he and Mr. Pedro G. Salom built in 1894. He exhibited photographs of trophies and other material relating to this car and detailed some of his experiences in the races held at that time.

Mr. Meyer invited the audience to visit Wood's Garage at Twenty-first and Market Streets after the meeting for the purpose of examining more closely the various kinds of electric vehicles. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, April 7, 1910, at 8 P.M., with Dr. E. Goldsmith in the Chair. Thirty-five members and visitors were present. Dr. Robert H. Bradbury, of the Southern Manual Training High School of Philadelphia, read a paper upon the "Chemistry of Colloidal Matter" in which he described the chemical and physical properties of colloidal solutions and discussed the distinctions between suspensions, colloidal solutions and true solutions. The lecture was illustrated by experiments.

Dr. Edgar T. Wherry, of Lehigh University, presented a communication upon the "Colloidal Nature of the Complex Inorganic Acids." Substitution of one oxide by an equivalent quantity of a similar oxide, *e.g.*, phosphorus pentoxide by arsenic pentoxide, changes the ratio of all the oxides to each other. Moreover, certain of the tungsten complexes crystallize in the isometric system, as is shown by measurement of the crystals, but have orthorhombic structure, as is shown by their behavior toward polarized light. Hence these compounds probably are absorption colloids in which the physical molecule of tungsten trioxide is composed of its chemical molecules, arranged in the isometric system (octohedron truncated by a cube). The chemical molecules of the other oxides are arranged in the spaces between the chemical molecules of the tungsten triocide, and thus produce a stress in the physical molecule of the latter, and causes the orthorhombic structure revealed by polarized light.

On motion of Dr. Williams a vote of thanks was extended to both speakers. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Photography and Microscopy.—Regular meeting of the Section was held in the Lecture Room of the Institute on Thursday, April 14, 1910, at 8 P.M. Dr. Henry Leffmann, President of the Section, in the Chair. J. W. Ridpath, Secretary of the meeting. Eighty members and visitors were

present. The minutes of the last meeting of the Section held February 24th having been recorded, their reading was dispensed with.

Mr. J. W. Ridpath was introduced, and read a paper upon "Unusual Trees," describing many trees of historic interest and others of unusual form or size. The paper was illustrated by about 50 lantern slides, showing many curious growths, including several specimens of natural or wind grafting.

Dr. Henry Leffmann exhibited fifteen photomicrographs of rock sections, taken with polarized light, showing the beautiful, brilliant colors, as seen with the polariscope.

Mr. Theodore Alteneder exhibited a few slides of flowers taken by the Lumiere process, showing the natural colors in beautiful gradations.

After some general discussion the meeting adjourned at 9.30 P.M.

J. W. RIDPATH,
Secretary.

PURIFICATION OF FACTORY WASTES.

INVESTIGATION IN RHODE ISLAND.

Under an agreement between the United States Geological Survey and the Rhode Island State Board of Health an investigation covering eleven months was made in 1906 and 1907 to determine the effects of certain industrial wastes on streams, their relation to health, their damage to natural water resources, and the best methods of disposing of them, purifying them, or recovering valuable materials contained in them. At the close of the co-operative work the state board of health continued the purification experiments for several months. A paper containing some of the results of this investigation has just been published by the United States Geological Survey as Water-Supply Paper 235.

Wool is impregnated with many impurities which must be removed before it can be used in the manufacture of textiles. The common methods of cleansing it produce great quantities of foul liquors, which contain valuable substances that can usually be recovered profitably, with coincident purification of the liquors. The suds from scouring with soap, alkali, and water is the most common waste scouring liquor in the United States. The authors discuss various methods of purifying this liquor and conclude that the most profitable is one in which the essential features are concentration and then treatment in a centrifugal machine similar to the ordinary cream separator. This process entirely disposes of the scouring liquor, the products being distilled water, wool grease, crude potassium carbonate, and earthy matter. The distilled water is useful for scouring and the wool grease and potassium carbonate have a considerable market value.

The waste waters from yarn bleaching can be purified by treatment with sulphuric acid and filtration. The wastes produced in bleaching cotton piece goods can be purified by sedimentation, precipitation, and septic treatment, followed by bacterial filtration with either sprinkling or sand filters. Dyehouse wastes can be satisfactorily purified by filtration through sand or by precipitation with lime.

The industries of making oleomargarine, fertilizer, and glue are closely allied, the raw materials being the wastes from slaughterhouses and markets. The processes, however, vary greatly in different plants. The authors conducted experiments at a fertilizer plant where the waste water is a putrescible, ill-smelling liquor containing an average of nearly fourteen million bacteria per cubic centimeter. This liquor can be purified by sand filtration at a cost of 5 to 29 cents per 1,000 gallons, according to the size of the filter plant. Another method consists of evaporating and drying the waste, the value of the recovered products—nitrogen, phosphoric acid, and potash—being about equal to the cost of treatment.

BOOK NOTICES

THE QUALITY OF SURFACE WATERS IN THE UNITED STATES. Part I.—Analyses of Waters East of the One Hundredth Meridian, by R. B. Dole. Contains 123 pages, 8vo. Water Supply Paper No. 236, United States Geological Survey. Washington, Government Printing Office, 1909.

Waters taken from rivers and lakes in the United States have been examined by chemists of the United States Geological Survey during the last four years to determine their mineral content, and especially their fitness for use by factories and for domestic purposes.

The volume contains the results of over 5000 mineral analyses of water from the principal rivers of the United States east of the Rocky Mountains. Daily samples of water from nearly 200 stations were collected for a year, united in sets of ten consecutive samples from the same station, and the composite subjected to analysis. The analyses giving, as they do, the average composition of the waters, the fluctuations of composition from day to day, and information regarding change of water level wherever available, form the most complete collection of data regarding the quality of American rivers that has ever been published.

This paper is the first of a number of reports on an exhaustive series of analyses made by the Survey to determine the quality of the surface waters of the United States. It gives the methods of analysis, the location of the sampling stations, and the analytical results, the demand for the data having been great enough to justify the publication of the analyses before their detailed discussion. Another report soon to be issued will discuss the analyses in relation to stream flow, climate, forestation, geologic environment, pollution, and other factors. Still another report will consider the quality of the waters in special reference to their availability for industrial use, and a paper on chemical denudation in the United States will discuss aqueous erosion in relation to geologic time.

The report may be obtained without cost by applying to the Director of the Geological Survey at Washington.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Vol. I, Alcohols, Carbohydrates, Yeast Esters, Aldehydes, Vegetable Acids. Edited by Henry Leffmann, M.A., M.D., and W. A. Davis, B.Sc., A.C.G.I. Fourth Edition, entirely rewritten x + 576 pages, 9 x 6 inches. Cloth, price $5.00 net. P. Blakiston's Son & Co., Phila., 1909.

The preparation of a new edition of this valuable treatise has been conducted in accordance with the views of the late distinguished author, consisting in allotting the revision to specialists, each entrusted with the task of bringing a particular section up to date. With the present extended development of organic chemistry, full justice to the subject can scarcely be expected from the labors of a single author and the wisdom of the collaboration plan is unquestionable. The contributors are both American and foreign, giving the work an international character. The original arrangement of subject matter remains substantially as before, only such changes in the distribution of topics having been made as are of distinct advantage. The work will consist of eight volumes which the publishers announce will be issued as quickly as is consistent with good work.

L. E. P.

CURRENT TOPICS

ADIABATICALLY COMPRESSED AIR AS A SUBSTITUTE FOR MECHANICAL TRANSMISSION IN MOTOR VEHICLES.—The adiabatic compression and expansion of air is compared with the isothermic, theoretically by diagram and by well-known formula, in order to call attention to the considerable advantage of the former method with regard to the work utilized. In this application the maximum pressure is limited to 15 atmospheres, the temperature of which is 363° C., and the compressed air nearly reaches that temperature in the receiver. This application is applied to a petroleum motor car to give the motor couple, on transmission, the value of that of a steam engine, without employing the usual clutches and speed changing gear. The petroleum motor acts through an epicycloidal train differentially upon the transmission and an air compressor which progressively brakes the exterior portion of the train. The air from the compressor is utilized immediately in a motor and counterbalances the couple of resistance of the apparatus. As the speed increases the effect of the air diminishes until it becomes nil and the car is propelled directly by the petroleum motor. (C. Hautier, *Comptes Rendus*, 34. 149.)

ALLOYS OF COBALT.—Cobalt and tin, in the liquid state, are miscible in all proportions, but solid cobalt dissolves only about 3.5 per cent. of tin. Two definite compounds, CoSn and Co_2Sn are formed. Cobalt and antimony also mix in all proportions in the liquid state. Solid cobalt can take up 12.5 per cent. of antimony, forming the compounds CoSb and $CoSb_2$. Cobalt and lead form no definite solid compound, and even when liquid each dissolves only a small quantity of the other. The same law applies to the alloys of cobalt with bismuth and thallium. Cobalt and zinc, fused together, deposit alloys in which the definite compound $CoZn_4$ has been found. Cobalt and chromium mix in all proportions, both in solid and liquid form. Cobalt and silicon mix in all proportions, when liquid, and form five definite solid compounds, Co_2Si, CoSi, $CoSi_2$, $CoSi_3$, and $CoSi_4$. (*Sci. Amer.*, March 5, 1910.)

ALL-STEEL CARS.—The Pennsylvania Railroad Co. announced on August 12, 1906, that all future passenger equipment would be built of steel, and of a design such as to render it indestructible either by collision or fire. In planning the cars and establishing standard types no expense was spared to build a coach

of the greatest possible strength, with an absolutely incombustible inside lining which should also be a poor conductor of heat and noise. There are now in service 245 coaches, 10 dining cars, 21 combination passenger and baggage cars, 29 baggage cars, 18 postal cars, and one company car, making a total of 324 steel cars. The Pullman Co. has been building some all-steel parlor and sleeping cars, and about 500 of them will shortly be placed in service. During the present year the P. R. R. Co. have ordered some 250 cars to be built. (*Sci. American*, Feb. 26, 1910.)

AMERICAN ELECTRO-CHEMICAL SOCIETY.—The annual convention of the American Electro-Chemical Society will be held at Pittsburg. The electric-steel furnace is no longer considered with suspicion or contempt by the practical iron and steel man. It is recognized as a very useful adjunct to the Bessemer converter and open-hearth steel plants, and before many years will be in extended use in steel works. The convention will visit two steel works where electric refining furnaces are in operation. (*Metall. and Chem. Eng.*, viii, 4.)

ARTIFICIAL RUBIES AND SAPPHIRES.—Artificial rubies are obtained by fusing alumina with 2.5 per cent. of chromium oxide in a Verneuil flame and taking care, first, to conduct the fusion in that part of the flame which is rich in carbon and hydrogen and not hot enough to cause ebullition of the mass; second, to crystallize the mass in layers superimposed from below upward, which allows the growth by a series of thin layers and gradual solidification; third, to limit the contact of the fused product with the support to an extremely small surface, in such a way as to diminish the number of fissures.

The fusion should last two and one-half hours. Synthetic rubies have the same properties as natural rubies. They have two defects, similar to those of glass, and invisible to the naked eye, only discoverable by the microscope: these are unequal distribution of the bubbles, and the striations which mark the zones of increase and are due to the volatilization of chromium oxide, causing a discoloration of that portion.

M. Verneuil has also succeeded in reproducing sapphires synthetically by fusion. The oriental sapphire owes its blue color to the presence of a small quantity of a lower chromium oxide.

Saint-Claire Deville and Caron concluded from their researches that the difference in the color of rubies and sapphires is either due to the proportion of chromium oxide or to the state of oxidation of the chromium. By the methods of Fremy and Verneuil only pale rubies or colorless corundum, can be produced. Similar experiments with iron peroxide, instead of

chromium sesquioxide, have given dark blue colored crystals, which appear still darker by artificial light, and appear to correspond to Australian sapphires.

If a small quantity of titanic acid is introduced, together with magnetic iron oxide, there are produced by fusion in the oxy-hydrogen flame, beautiful sapphires colored by a minimum of iron oxide. M. Verneuil has produced them from alumina with the addition of 1.5 per thousand of magnetic iron oxide, and 1 per thousand of titanic acid. Hence there are two kinds of sapphires, those colored by chromium oxide and those colored by iron oxides and titanium oxide. (*Bull. de la Société d'Encouragement*, 113, 1.)

CARBON TETRACHLORIDE AS A FIRE EXTINGUISHER.—If carbon tetrachloride is squirted onto a fire from a receptacle fitted with a nozzle and a plunger, its heavy noncombustible vapor acts as a blanket and shuts out the oxygen of the air necessary to support combustion. As it is inert and non-corrosive, the extinguisher when once charged needs no attention until it requires replenishing. The vapor volatilized by heat has an anæsthetic effect, and if used in a closed space, this space should be well ventilated.

In its liquid state it is miscible with gasolene and if present in sufficient proportion renders the mixture non-inflammable. It is not injurious to fabrics, and is an excellent solvent of grease spots, for which use it is sold under different trade names. (*Horseless Age*, Jan., 1910.)

CARBON TETRACHLORIDE VAPOR.—The vapor of CCl_4 acts on mineral metallic oxides transforming them to chlorides, as readily as on artificial products, if they are sufficiently finely divided. Silica is not attacked; anhydrous silicates are attacked in inverse proportion to their content of silica, while hydrated silicates are completely transformed. The separation of the volatile chlorides, and the removal of the insoluble silica from the residue, makes this process valuable in mineral analysis, and in the detection of oxide in non-oxide minerals, such as molybdenite. (P. Camboulives, *Comptes Rendus*, 150, 221.)

CHARDONNET ARTIFICIAL SILK.—A method, which is stated to be successful, has been operated since 1906, in a Hungarian artificial silk factory. It consists of operating the reels on which the artificial silk is wound by means of a roller on which water is sprinkled. The water washes the solvent out of the wet fibres, the supply is regulated so that the liquid recovered from the roller contains about 14 per cent. of ether-alcohol, which can be recovered by distillation. (A. Vajdafg, *Chem. Zeit.*, 34, Rep. 75.)

CONDUCTIVITY OF METALS AT HIGH TEMPERATURES.—If a long thin platinum wire is twisted into a spiral round a glass rod, and the spiral heated to redness by an electric current, and the lower portion dipped into cold water in a beaker, then the upper portion becomes white hot, *i.e.*, the current has become greater and the resistance of the cooled end of the wire has become less. If too much of the spiral is immersed, the wire melts, especially if a mixture of carbon dioxide and ether is used for cooling.

CYLINDER LUBRICATION.—In connection with Prof. C. F. Mabery's paper on "Lubrication and Lubricants" (a synopsis of which appeared in the April issue of this JOURNAL) users of cylinder oils were invited to submit data as to their practice. A table of their replies appears in the *Iron Age* for February 17, 1910, which is well worth careful study. Remarkable differences are to be noticed in the cost per thousand estimated horse-power per hour, ranging from 0.47 cents to 30 cents; and in the amount of oil used per 1,000,000 square feet of surface rubbed over per hour, ranging from 0.07 to 5.94 pints. By comparing this table with the results obtained in their own plants, users will be able to conclude whether they are, or are not, using cylinder oil economically.

DECARBURIZATION OF CAST-IRON BY GASEOUS OXIDIZING MEDIA.—White cast-iron rods containing 0.35 per cent. of silicon, 0.17 per cent. manganese, 0.03 per cent. phosphorus, 0.02 per cent. sulphur, 3.18 per cent. of carbon and free from graphite, both before and after tempering in a vacuum for 10 hours at 950° C. were heated in a Heræus electric furnace for five hours, and about three litres of a mixture of pure dry carbon dioxide and carbon monoxide were passed over them. The temperatures used were 800° C., then 900° C., and 1000° C., and the percentage of carbon dioxide in the gaseous mixture was determined before and after being passed over the heated iron. The weights of the metal before and after the experiments indicated that the decarburization increased with the increase of carbon dioxide content and with the increase of temperature. There is also a danger of an oxidation of the iron as the carbon dioxide increases, but experiment showed that no observable oxidation took place at 800° C. in a mixture containing 30 per cent. of carbon dioxide, nor at 900° C. with 28 per cent., nor at 1000° C. with 24 per cent. of carbon dioxide. Decarburization is slow at 800° C. and the most practical condition seems to be the use of a mixture containing 24 per cent. of carbon dioxide and 76 per cent. of carbon monoxide at a temperature between 900° C. and 1000° C. (H. Becker, *Metallurgie*, 1910, 7, 41–59.)

DYEING OF WOOL.—The author agrees with the theory that wool contains amino, imino, and carboxyl groups, as only by this constitution can it be explained why wool mordanted with tin tannate loses its affinity for acid dyestuffs. This loss of affinity also occurs when hydroxyl and carbonyl groups are introduced by the dyestuffs, etc., used. (M. Saget, *Monit. Sci.*, 24, 80.)

ETYMOLOGY AND HISTORY OF THE WORD 'GAS.'—J. B. van Helmont was the first to differentiate the aeriform substances (which behave differently), from common air and vapors, and these he arbitrarily called 'gases.' No reason can be assigned for the point of view which led him to coin this word; from a comparison with the 'Dünste' (vapors) and the 'chaos' of the old authors. No hint can be drawn as to its etymological derivation from the word chaos. Von Lippmann states that the word chaos expressed in antiquity the origin of all things. The author proceeds to describe the labors of other investigators to determine the etymology of the expression 'gas,' from the time Van Helmont coined it, which has remained the same to the present day, in spite of manifold and great changes in the idea. (Max Sheter, *Chem. Ztg.*, 34, 193–194.)

EXPLOSIVE COAL DUST.—Recent experiments have proved conclusively that coal dust which is so fine as to pass a 200 mesh sieve, will explode on contact with either a naked flame or with the arc of an electric current. (*Sci. American*, Feb. 26, 1910.)

HISTORY OF THE WORD 'GAS.'—Van Helmont was the first to use the word 'gas,' and claimed the new word. Paracelsus had already spoken in the "Paramirum," and in other places, of 'Chaos-kälte' in a sense which justifies his 'chaos' as equivalent to 'gas,' thus "the element 'aer' is nothing but a perfect chaos . . . ; and . . . is known as the element air (atmosphere) or chaos." The expression chaos at any rate originated with Paracelsus. Presumably Van Helmont derived it from Paracelsus without any distinct recollection, and his 'gas' can be traced to the word 'chaos.' (G. O. von Lippmann, *Chem. Ztg.*, 34, 1.)

HYDROGEN FOR THE INFLATION OF PNEUMATIC TIRES.—The laborious operation of inflating automobile tires may be avoided by the use of cylinders of compressed air. But such cylinders cannot always be conveniently replenished when exhausted. The idea is put forward of substituting hydrogen for compressed air. This hydrogen is generated by the decomposition of water by aluminum in the presence of alkalies,

or mercury bichloride. Ten ounces of granulated aluminum and ten ounces of water, with a little mercury bichloride are placed in an air-tube of six and one-half pints' capacity (such as are usually furnished by the tire makers) and the bronze plug quickly screwed down. In a few minutes the air-tube is filled with hydrogen at a pressure of 150 atmospheres, *i.e.*, more than 100 gallons of hydrogen at atmospheric pressure are generated. Approximately 20 ounces of alumina are formed simultaneously which can be readily washed out when the air-tube is empty. This simple method enables an automobilist to recharge his air-tubes and to inflate his tires with hydrogen instead of air. Graham's law of the diffusion of gases through porous walls, is that the rate of diffusion is inversely proportional to the square root of the density of the gas, but the rate of diffusion through colloidal substances, such as rubber, is directly proportional to the facility with which the gas can be liquified. By supplying the ingredients in cartridges of the proper volume for a given size of cylinder, or by providing each cylinder with a safety valve, any danger of overcharging and rupturing the cylinder may be avoided. This method of generating hydrogen for inflating balloons was used in the Russo-Japanese War, but its application to the production of cylinders of compressed hydrogen appears to be new. (Druilly in the *Scientific American.*)

NEW HIGH-SPEED TOOL-STEEL.—The Electric Steel Co., of N. Y., is building a plant at New Milford, Conn., for producing a new high-speed tool-steel under the Louis Auricchio process. Specimens of the steel made in an experimental furnace have been tested with exceptionally satisfactory results. (*Iron Age*, 85, 7.)

NON-SHRINKING ALLOY.—Tin, 50 pounds, and zinc, 50 pounds, gives a tough, hard metal, that runs well. It is improved by the addition of 2 pounds of bismuth. By the use of heavy sprues, and pouring cold, the slight shrinkage may be largely overcome. (*The Metal Industry*, Feb., 1910.)

OXIDIZED ALUMINUM WIRE FOR RAILWAY MOTOR COILS.—The resistance of the oxide film is sufficient to prevent short-circuiting between parallel adjoining wires of the same winding, when the difference of potential between them does not exceed 0.5 volts. Some other form of insulation is required between successive layers. Space can be saved and a better distribution of mechanical stresses secured by using square wire. A successful aluminum-wound motor means lighter weight, lower first cost and absence of short-circuits as caused by the charring of cotton insulation. The decrease in main-

tenance cost is particularly marked in the case of railway motors, because their insulation is most likely to be disintegrated by shock. (Paulsmeier. Paper read before the German Street and Interurban Railway Association.)

PHOSPHORESCENCE OF THE SULPHIDES OF ALAKALINE EARTHS.—The phosphorescent properties of barium-, strontium-, and calcium-sulphide, which have been lost by exposure to air, can be revived by heating the sulphides strongly in a current of dry hydrogen. The sulphide, either in small fragments or powdered, is placed in a refractory Bohemian-glass combustion-tube, tapered at one end, and with the other end connected to a large vessel containing pumice stone moistened with sulphuric acid, and thence to the gas holder. The tube is placed in a combustion furnace, protected by asbestos. The air is first expelled by the hydrogen, then the tube is gradually heated until the glass begins to soften and held at that temperature for 15 to 20 minutes. The stream of gas is stopped, the tapered end of the tube sealed with a blowpipe, and the contents are allowed to cool, in the enclosed atmosphere of hydrogen. During the heating a series of small explosions occur, and some drops of water condense in the cool parts of the tube, and sometimes a little sulphur is deposited. After cooling the sulphide has completely recovered its phosphorescence. Heat alone, without hydrogen, only produces a slight improvement. (D. Gernez, *Comptes Rendus,* 150, 295.)

PHOSPHOR-BRONZE.—In alloys containing less than 4.5 per cent. of tin, the phosphorus is present as rounded, more or less detached particles of copper phosphide, Cu_3P, the tin being in solution in the copper. With more than 4.5 per cent. of tin the alloys contain a ternary eutectic of copper, Cu_3P, and Cu_4Sn. Copper is capable of holding a small quantity of phosphorous as well as tin in solution as occurs in the malleable phosphor-bronzes in which tin does not exceed about 6 per cent. and phosphorous 0.3 per cent. (*Inst. of Metals,* Jan., 1910.)

POLISHING METALS BY A "RUBBING-IN" PROCESS.—A compound named "Galvanit" is claimed to clean and polish metal, not by removing the tarnished surface by abrasion, but by adding metal to the surface to be polished, by a species of electroplating. Provided the objects are reasonably clean they can be plated without any preliminary cleansing treatment.

The composition of the "Galvanit" powder necessarily varies according to the particular metal to be deposited. All metals generally deposited by the battery process can be deposited by the "Galvanit" process, and also many alloys. Speaking gen-

erally, any given metal can be deposited on the same metal or on any other metal. The mixtures employed comprise some form, either elementary or combined, of the metal to be deposited and secondly an electro-positive metal in the uncombined form, and thirdly, a substance which is capable of producing an aqueous electrolyte when brought in contact with moisture. The electro-positive metal employed is generally magnesium; but in some cases a less electro-positive metal, such as aluminum, zinc or cadmium works very well. The choice of the electro-positive metal or anode, depends on the metal to be deposited and upon the nature of the receiving surface, or cathode, to be coated. In practice it is found that by mixing a salt with an electro-positive element, such as zinc or magnesium, a violent reaction takes place, evolving great heat, and the mixture is spoiled, or in any case the deposition is too rapid or of bad color. It is therefore advantageous to add some inert substance, which acts as a diluent and as a polishing medium, *e.g.*, chalk, talcum, boracic acid and so forth. To avoid this difficulty of premature action, it is better to use the metal to be deposited rather than a salt of the metal. The requisites then are (1) the metal to be deposited, (2) a salt, preferably an ammonium salt, and (3) the electro-positive metal; and to keep the mixture dry and to prevent the salt acting on the electro-positive metal, some inert ingredients, as for example:

	Parts by weight.
Zinc	15
Ammonium sulphate	5
Magnesium	1
Chalk	10
Soapstone	2.5

If it is desired to deposit some other metal, for instance cadmium, then cadmium is substituted for zinc.

As in the wet processes, in some cases acid baths, and in others alkaline baths, are preferable, so it is desirable in the "Galvanit" process to add acid or alkaline ingredients to produce the requisite reaction in the presence of moisture, to form an acid or alkaline electrolyte. In this reaction the electro-positive metal constitutes the anode and the object treated the cathode, and as the "Galvanit" contains a quantity of finely powdered electro-positive metal it makes innumerable contacts with the cathode surface, and acts as so many minute anodes; thus the surface of the metal is the seat of concomitant voltaic and electrolytic actions, and as these currents leave the liquid they throw down a thick film of metal from the metallic salt in solution on the cathode and plate it.

The remainder of the article goes fully into the theoretical

considerations of the process and is worth careful perusal. (Augustus Rosenberg, *Journ. of Soc. of Arts.*)

PROCEEDINGS OF THE INTERNATIONAL COMMISSION ON ATOMIC WEIGHTS.—

Chlorine.—By passing nitrosylchloride, NOCe, over silver to remove chlorine, then over heated copper to remove oxygen and finally over metallic calcium to absorb nitrogen, a full analysis of this compound was made. From the ratio of oxygen to chlorine it resulted that the At. wt. of chlorine is 35.468, and *nitrogen* is 14.006.

Carbon.—Baumé and Perrot have found from the density of methane that carbon = 12.004. From the density of toluol vapor, as determined by Ramsay and Steele, Leduc finds carbon = 12.003.

Iodine and Silver.—Baxter and Tilley have determined the ratio between iodine pentoxide and silver. They conclude that silver lies between 107.847 and 107.850. The corresponding value for iodine is 126.891.

Phosphorus.—From the density of phosphoretted hydrogen, PH_3, Ter Gerzarian finds the value of phosphorus = 30.906.

Arsenic.—Baxter and Coffin compared the ratios of silver arsenate with silver chloride and silver bromide respectively, by two methods. For the value 107.880 for silver, the final mean of arsenic was 74.957.

Chromium.—Baxter, Müller, and Hinnes found by the analysis of silver chromate a mean value for chromium of 52.008, when silver is 108.88. Similar analyses of silver dichromate gave Baxter and Jesse for chromium the value 52.018. This gives chromium a mean value of 52.01.

Tellurium.—Lenher led the double potassium tellurium bromide over potassium chloride, and then heated it in a current of chlorine and lastly in hydrochloric acid. The mean value from 16 experiments gave Te = 127.55.

Mercury.—Easlay found the unusually high values of 200.48 and 200.62 for mercury; but as he is still continuing his investigation, it is not desirable to accept his figures until his work is completed.

Palladium.—Gutbier, Haas, and Gebhardt analysed palladosammonium bromide and found as the most probable mean value Pd = 106.689.

Krypton and Xenon.—Moore isolated both gases in considerable quantities from the residues of liquid air. From the densities of the two gases he found Kr = 83.012 and Xe = 130.70. (F. W. Clarke, and others, *Zeit. für ang. Chem.*, xxiii, 1, 21.)

SPECTRUM ANALYSIS.—The solar spectrum and the stellar spectra are comparable to arc electra, that is to the spectra of very hot flames. But the spectra of the lines of hydrogen and

helium show that the solar spectrum is modified by electrical phenomena. I propose as an hypothesis, that the spectrum of the elements present in the sun resemble the arc spectrum, because its production is either due to, or accompanied by, electrical discharges. If in the spectrum of dissociation of a metallic compound, or of an alloy, we get the lines of its constituents, and all the rays of its spark spectrum, including those of the arc, the total *limit of apparition* is reached or passed. As these diminish, only the rays of the arc appear, and finally only the rays of the arc-light. If, as an hypotheses, these results are applied to the sun, it explains on the one hand, how the ultimate rays are found in all the Solar regions, and on the other hand, how the spark rays acompany those of the arc in the spectra of the sun spots.

But in the highest parts of the chromosphere, a very small number of spark rays are visible as well as the ultimate rays. These spark rays are the *enhanced lines* which Sir Norman Lockyer attributes to the *proto-elements* resulting from the dissociation of simple bodies. This term might be given them whenever they are found separated from the complete spectrum to which they belong. On the contrary they correspond to a great tenuity of the ordinary element not dissociated, when they are included in the complete spectrum to which they belong. There are found then in the higher zones of the chromosphere, at the same time, very rarified gases of the integral element and the products of its incipient decomposition.

On the whole then this hypothesis supposes that the spectra of the different regions of the sun are the spectra of dissociation and that their differences are principally due to the variations in the proportions of the elements present.

As to the spectra of the metalloids which have not been recognized in the sun, it should not be concluded that the elements are not present in the sun, nor that their spectra are assimilated in an arc spectrum. I have shown recently that rays of great perceptibility and the ultimate rays of several of these metalloids are situated in that part of the ultra-violet absorbed by the terrestrial atmosphere. But the field of astronomical spectroscopy is limited not only by atmospheric absorption, but also by the instruments used (silvered mirrors or flint lenses) and by the sensitiveness of the present photographic plates.—(M. A. de Gramont, *Comptes* Rendus, 150, 37.)

TESTING DAMP-PROOF MATERIALS.—The problem is to find a material which could be applied to an existing structure without altering materially the natural color or general appearance of the concrete, and which would prevent the absorption of rain. The material therefore had to be a colorless solution or wash, thus excluding all materials containing a pigment.

Nineteen samples of compounds which the makers claimed would do just what was required were obtained.

The method of testing was as follows: Several 3-inch cubes were moulded with a depression on one side large enough to hold about 40 c.c. of water. These were made of a rather dry mixture of one part of Portland cement and 3 parts of crushed granite by volume. The crushed stone was screened through a fine-mesh screen, giving particles varying from an impalpable powder to those just small enough to pass the screen, consequently the cubes were very porous and absorbent. After the cubes were set they were tested for porosity by filling the depression with water and noting the time required for absorption. Any cube requiring more than one minute to absorb the water was rejected.

After drying out thoroughly the side having the depression was given a liberal soaking coat of the damp-proofing composition under test. This was allowed to dry and a second liberal coat, or as much as the concrete would absorb, was applied.

After this second coat dried its efficiency was tested in this way: 30 c.c. of water were placed in each cup, a watchcrystal superimposed to prevent evaporation, and the cube left undisturbed until the water was completely absorbed. The efficiency of the compound was of course proportional to the time required.

After this the cubes were exposed to the weather for several months and again tested as before. On the first test five required less than one hour to absorb the water; four required more than one hour but less than one day; seven more than one day but less than one week; and three held water for more than one week.

On the second test, seven stood less than one hour; eleven more than one hour but less than one day; and one held water for more than one day and lasted nine days.

Nine darkened the surface of the concrete, one made it lighter and the remaining nine had little if any effect on the color. (C. M. Chapman, in a paper before the *National Association of Cement Users.*)

THROUGH THE AIR.—Whether with rigid- or flexible-framed dirigible, monoplane or biplane, aeroplane, or the combination and blending of two or more of these types, aerial progress is constant and consistent. The constant incentive furnished by the efforts of the military authorities of every nation ensure no loss of interest in the subject. It is not rash to say that we shall come to the final form of airship, sooner than was possible with land vehicles or sea-going ships. (*Arms and the Man*, xlvii, 26.)

THE TRANSFORMATION OF SELENIUM.—Selenium is found in three conditions: *vitreous*, red in thin sheets; *crystallized*, red; and *metallic*, black in thin sheets. These three states are characterized by different densities.

Pure vitreous selenium quickly cooled in a vacuum has the density 4.302. When reduced to powder after boiling in toluol, however, its density is 4.80. By the action of a concentrated solution of potassium hydroxide on selenium at 230° C. and slow cooling, it is obtained crystallized in long needles, with a density 4.82. Its fusion point in a Maquenne block is 219°.

The density of red selenium crystallized by contact with carbon disulphide at a temperature of 20° C. is 4.455. This selenium has little stability, its color darkens as the temperature rises. (M. Maurice Coste, *Moniteur Scientifique*, Jan., 1910.)

ZIRCONIUM DIOXIDE.—Natural Brazilian zirconia contains 85–90 per cent. of zirconium dioxide. Its specific gravity is 4.9 and its hardness about 7. Pure fused zirconium has a very small coefficient of expansion (linear coefficient = 0.00000084) and can be plunged into cold water when white hot without fear of fracture. Its density is 5.75. It is very difficult to melt, and vessels said to be made of the fused oxide contained alkali. Crucibles made of 9 parts of the oxide and 1 part of magnesia, with 10 per cent. of phosphoric acid as a binder, are not at all affected by sudden changes of temperature, and are practically unattacked by fused alkalies or bisulphate. The oxide can replace lime and silica in glass manufacture. It is not reduced by aluminum, but if this oxide be mixed with ferric oxide, aluminum reduces them to an alloy of zirconium and iron. To obtain the oxide, 100 parts of powdered mineral is mixed with 120 parts sodium sulphate and 35 parts powdered carbon, one-third of its weight of sodium chloride is added as a flux and the mixture is very strongly heated in a blast-furnace; the product is powdered and boiled in water several hours, the residue, containing iron sulphide, filtered off, treated with hydrochloric acid, again filtered, and the carbonaceous residue ignited. —(*Zeit. Anorg. Chem.*, 65, 178.)

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